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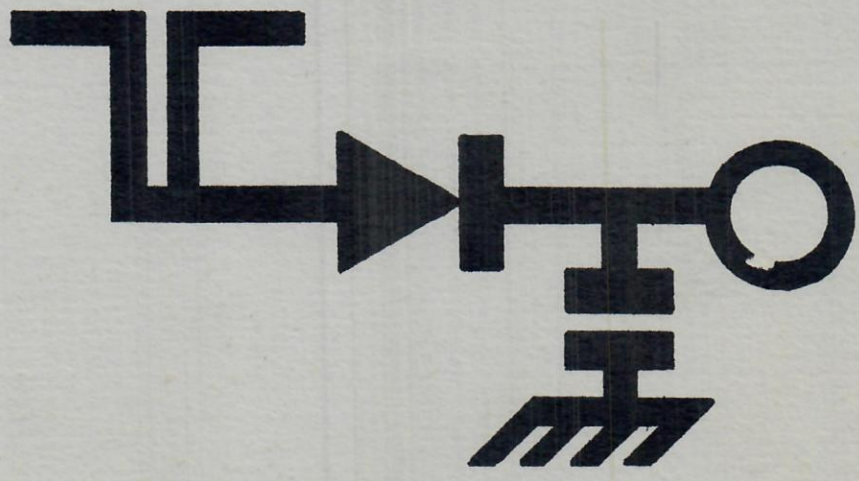
ANSWER MANUAL

COMMUNICATIONS BOOK III



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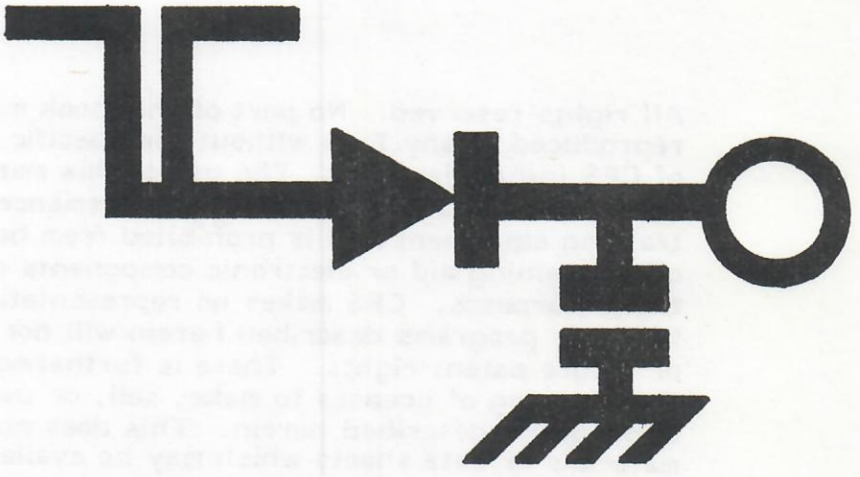

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ANSWER MANUAL

COMMUNICATIONS BOOK III

UNIT NO.

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TABLE OF CONTENTS

1. Feedback Oscillator
2. Hartley Oscillator
3. Colpitts Oscillator
4. Clapp Oscillator
5. Phase Shift Oscillator
6. Amplitude Modulation
7. AM Broadcaster & AM Detector
8. Radio Detector
9. Audio Output Amplifier
10. Audio Preamplifier
11. Complementary Audio Amplifier
12. AM Radio Receiver and Varactor Diode
13. Frequency Modulation
14. Audio Transformer
15. Single-Ended Transformer Amplifier
16. Push-Pull Audio Amplifier
17. AM Transmitter, Collector Modulation
18. Superhetrodyne Receiver and Local Oscillator
19. Mixer Converter
20. Variable Gain Amplifier and AGC
21. I.F. Tuned Amplifier
22. Receiver Alignment
23. AM Radio & Amplifier
24. Receiver Troubleshooting

25. Filter Response and Decibels
26. Frequency Traps
27. Image Frequencies
28. R.F. Amplifiers
29. Crystal & Filter Circuit
30. Crystal Oscillator
31. Frequency Multiplication
32. CB Radio
33. FM Transformer
34. Demodulators & Slope Detector
35. FM Discriminator Detector
36. FM Test Generator
37. FM Ratio Detector
38. Single Sideband & Balanced Modulator
39. Stereo Multiplexing
40. Linear Integrated Circuit

** Errata Information

FEEDBACK OSCILLATOR

To build and test a Feedback Oscillator. The circuit is assembled and the emitter resistor is adjusted while monitoring the output waveform to obtain an undistorted sine wave output. The output waveform amplitude and frequency are recorded and the waveform is sketched. Then the circuit is built using a Silicon Transistor, and FET, a PNP transistor and a Triode electron tube.

The 100K POT provides an adjustable base bias voltage to Q5 through the secondary winding of T2. The 10 ufd capacitor from the bias to ground is a bypass capacitor which connects one end of the secondary of T2 to ground for the high frequency oscillations. This means that the secondary of T2 appears to be connected from the base of Q5 to ground for high frequencies Therefore, any A.C. voltage on the secondary of T2 drives the base of Q5. The collector of Q5 is connected to a tuned circuit consisting of the primary winding of T2 and the 150 pfd capacitor. A.C. signals in the primary are coupled to the secondary and become the input signal to the transistor base. The 10K emitter POT is used to adjust the gain of Q5 and permit undistorted sinusoidal oscillation. When the tuned circuit in the collector "rings" with A.C. signal, this signal is coupled to the secondary of T2 and becomes the input to the base of Q5. The transformer is phased so that this input to the transistor reinforces the signal in the collector. When the transistor gain is high enough, these oscillations will be self sustaining. The oscilloscope is used to measure the output oscillations and the meter is used to measure the bias voltages.

2. The 100K POT is adjusted so that the transistor is operating in the linear or active region and the circuit will oscillate. The 10K emitter POT is adjusted so the gain will allow sinusoidal or undistored oscillation.

$R_{(emitter)}$ = 12K ohm $Volts_{(BIAS)}$ = 2.8

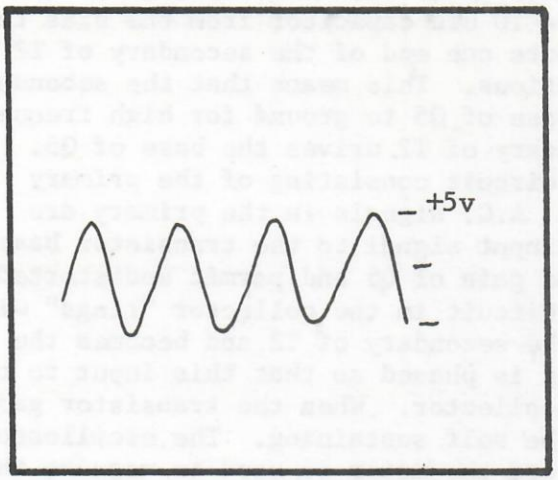
3. The emitter potentiometer is set at "0" ohms for maximum gain from Q5. The bias is then adjusted for oscillation. The bias is recorded.

V_{BIAS} = 0.2 volts

FEEDBACK OSCILLATOR

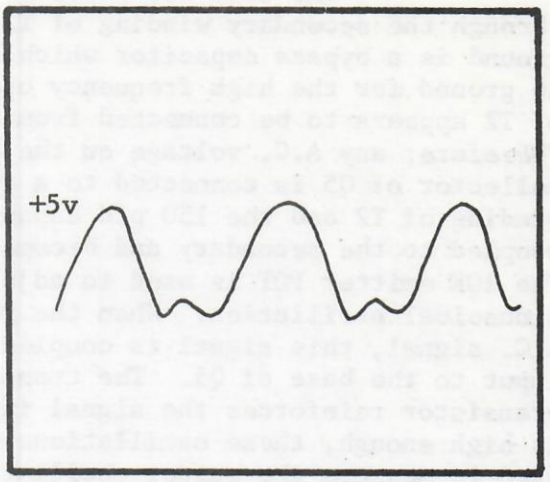
4. The sine and distorted waveforms are sketched.

NOTE: This circuit may oscillate anywhere between 200 KHz and 2 MHz depending upon the adjustment of the T2 tuning knob.



SINEWAVE OUTPUT

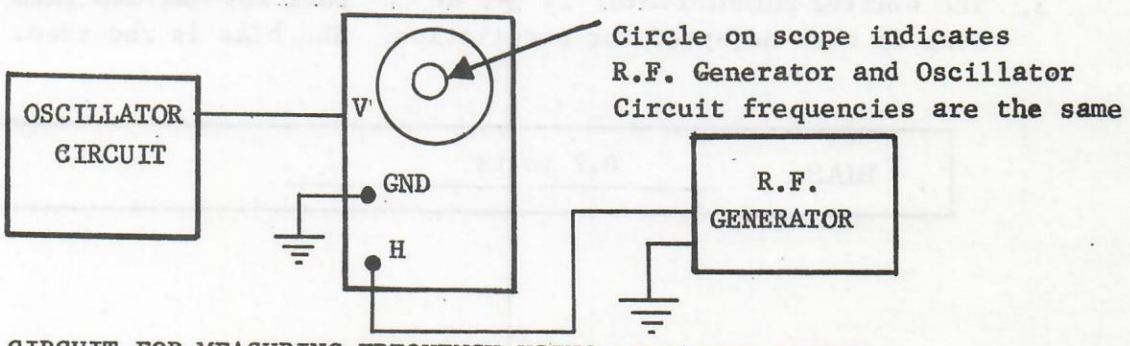
$R_{emitter}$ = 2K ohm



DISTORTED OUTPUT

$R_{emitter}$ = 0 ohms

5. Measurement of the Period of Oscillation. The period of oscillation can be measured directly on the oscilloscope if a scope with a calibrated time base is available. If there is no calibrated time base scope, then the frequency of the oscillation may be measured using a Lissajous Pattern. The circuit output signal is used to drive the vertical deflection of the oscilloscope and a calibrated R.F. oscillator is used to drive the horizontal scope deflection. When the R.F. oscillator frequency is the same as the frequency of oscillation of the circuit, the pattern on the oscilloscope will be a single loop or circle.



CIRCUIT FOR MEASURING FREQUENCY USING LISSAJOUS PATTERN

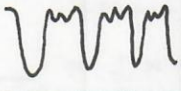
T = Period = 1.5μ sec

$$\text{Frequency} = f = \frac{1}{T} = \frac{1}{1.5 \times 10^{-6}} = 0.66 \times 10^{6} = 660 \text{ KHz}$$

Frequency = 660KHz

FEEDBACK OSCILLATOR

6. The same circuit is built using a Silicon Transistor, a FET, an Electron Tube and a PNP Transistor.

(After Adjustment)	$R_{emitter} = 0$	ADJUST		SINEWAVE (Yes or No)
	WAVEFORM	R_e =	BIAS =	
Germanium Transistor Q5		2K	0.2V	YES
Silicon Transistor Q7		10K	0.8V	YES
FET Transistor		5K	0	YES
Vacuum Tube 12AE6A		0	0	YES
PNP Transistor Q1		7KΩ	-0.7	YES

Note that the heater connections must be made to operate the tube.

The PNP Transistor must have the power connections changed from + to - because current flow is opposite to that in the NPN transistor.

HARTLEY OSCILLATOR

To build and test a Hartley Oscillator using an NPN transistor, then to repeat the circuit using a PNP transistor, a FET, and a Triode electron tube. The frequency of oscillation, and waveforms are recorded.

The Hartley Oscillator is an R.F. amplifier with a tapped inductor used as a feedback element. The 1M pot provides adjustable bias voltage to the base of Q4. The 10mhy choke in the collector of Q4 provides a high impedance at R.F. frequencies and acts as a collector resistor at the frequency of oscillation. This collector voltage is A.C. coupled to the bottom of the tuned circuit consisting of T2 and the 330pfd capacitor. Since the inductor is tapped with the tap connected to ground the voltage on the upper end of the inductor will be the opposite of the lower end or the collector voltage. Therefore, the voltage into the base of Q4 is 180° out of phase with the collector voltage. The transistor Q4 adds another 180° to the phase shift and the transistor collector drives the base circuit in such a way as to reinforce the oscillation. If the the transistor gain is high enough the circuit will oscillate.

2. Bias Adjustment

The 1 Megohm bias POT is adjusted to bias the transistor in the active or linear region of operation. When the transistor is biased in the active region the gain is maximum and the circuit will oscillate. The period of oscillation is measured and the frequency is determined.

$$T = \text{Period} = 2.1\,\mu\text{sec}$$

$$F = \text{Frequency} = \frac{1}{T} = \frac{1}{2.1 \times 10^{-6}} = 476\text{KHz}$$

OSCILLATING FREQUENCY (C = 330 pfd) = 476 KHz

3. Change in tank or tuned circuit capacitor from 330 prd to 0.01 ufd. This will change the resonant frequency of the tuned circuit and should change the frequency of oscillation.

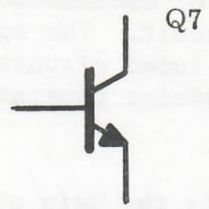
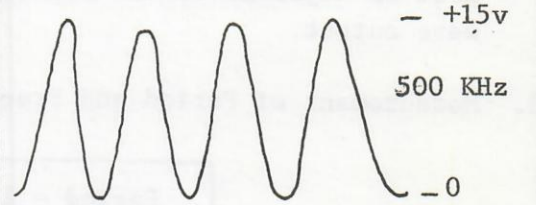
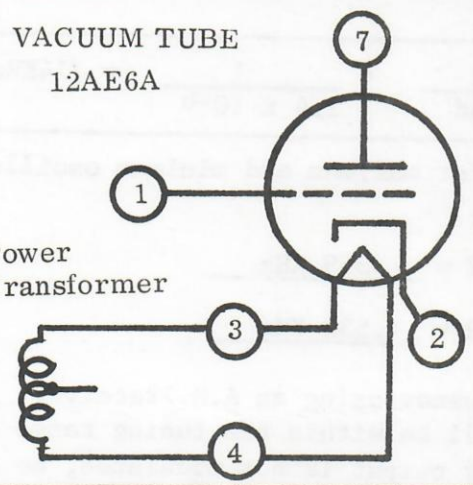
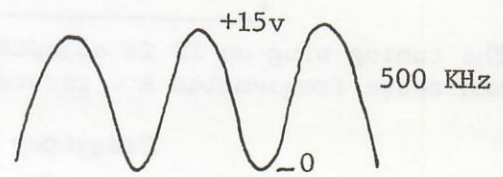
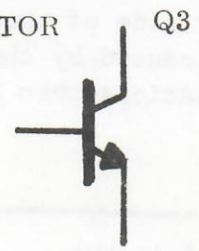
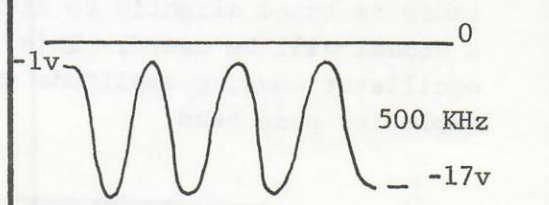
$$T = \text{Period} = 10\text{usec}$$

$$F = \text{Frequency} = \frac{1}{T} = \frac{1}{10 \times 10^{-6}} = \frac{1}{10^{-5}} = 100\text{KHz}$$

OSCILLATING FREQUENCY (C = 0.01 mfd) = 100 KHz

5. The same circuit is built using the Silicon NPN, PNP, FET and Triode electron tube. The waveform resulting from each circuit is recorded.

HARTLEY OSCILLATOR

ELEMENT	OBSERVATION
A. SILICON TRANSISTOR 	
B. FET TRANSISTOR	
C. VACUUM TUBE 12AE6A 	
D. PNP TRANSISTOR  also change +V1 to -V1	

COLPITTS OSCILLATOR

To build and test a Colpitts Oscillator circuit. The circuit is adjusted for sine wave oscillation and frequency is measured. Then the circuit sensitivity capacitance loading is measured by connecting a small capacitor between the elements of the transistor and measuring the effect on frequency.

The Colpitts Oscillator utilizes a split capacitor to generate the correct phase relationship between the collector and base signals for oscillation. Q5 is biased on by the 1 meg series resistor from power. The 10 mhy choke in the collector acts as a high impedance at R.F. frequencies and serves the function of collector resistor at the frequencies of oscillation. Inductor T2 and the series 220 and 330 pfd capacitors are the resonant tuned circuit that determined the frequency of oscillation. The collector is A.C. coupled to the bottom of the tuned circuit. The split capacitor is grounded at the center so the upper end of the tuned circuit will be 180° out of phase with the collector voltage. The transistor generates another 180° phase shift so the circuit will oscillate.

2. The 10K POT in the emitter controls the gain of the circuit. This POT must be adjusted so the circuit can oscillate with an undistorted sine wave output.

3. Measurement of Period and Frequency.

Period = 1.4 u sec

$$\text{Frequency} = \frac{1}{\text{Period}} = \frac{1}{1.4 \times 10^{-6}} = 714\text{KHz}$$

The tuning slug on T2 is adjusted for maximum and minimum oscillator frequencies and these frequencies are recorded.

Frequency LOW = 555 KHz

Frequency HIGH = 1.538 KHz

4. Measurement of oscillator frequency using an A.M. receiver. The R.F. signal generated by the oscillator will be within the tuning range of an A.M. receiver. Since the oscillator output is not modulated, no audio tone will be heard when the radio is tuned to eactly the oscillator frequency. If the radio is tuned slightly to either side of the oscillator frequency, however, a squeal will be heard. This is caused by the frequency variations in the oscillator causing amplitude variations when sweeping the skirt of the I.F. Amplifier pass band.

Frequency = 1.10 MHz

COLPITTS OSCILLATOR

5. Effect of A.C. coupling capacitors on the tuned frequency of the oscillator.

The A.C. coupling capacitors are very large capacitors in series with the resonant circuit. Since capacitors in series add like resistors in parallel, the overall tuned circuit capacitance will approximate the lower capacitance and varying the large capacitors will not affect the capacitance or resonant frequency of the circuit.

The two 0.25 mfd capacitors are A.C. Coupling capacitors and do not affect frequency.

Substitute 0.01 mfd capacitors for the 0.25 mfd caps and observe that there is no change in frequency.

Does the frequency change? NO

Substitutute 10 mfd caps for the 0.25 mfd caps and observe that there is no change in frequency.

Does the frequency change? NO

6. The fingers are placed across the transistor leads to test the circuits stability when the transistor capacitance changes. The results are recorded in a table.

Stray CAPACITANCE	FREQUENCY CHANGE
Base-to-Ground	LOWER
Collector-to-Ground	LOWER
Base-to-Collector	LOWER

CLAPP OSCILLATOR

To build and test a Clapp Oscillator, measure the frequency of oscillation and test the sensitivity to capacitive loading.

The Clapp Oscillator uses a split capcitor as does the Colpitts Oscillator. The tuned circuit for the Clapp Oscillator is the series circuit using T2 and 220pfd capacitor. The tuned circuit energy is coupled to the transistor emitter by the capacitor divider circuit. This is the feedback mechanism that sustains the oscillations.

2. BIAS ADJUSTMENT

The bias is adjusted with the 1 meg pot to bias the transistor in the active region for oscillation.

FREQUENCY = 1.11 MHz

3. The effect on the oscillator frequency caused by capacitive loading at various points in the circuit.

As in the previous experiment, place your fingers across the "base to ground" "collector to ground" and collector to base" and observe that the added capacitance has very little effect. What is the effect? How does this test compare with the Colpitss oscillator?

The Colpitts oscillator frequency changes when loaded capacitively. The Clapp oscillator is very stable and no change in frequency is noted with capacitive loading.

STRAY CAPACITANCE	FREQUENCY CHANGE
Base-to-Ground	NO CHANGE
Collector-to-Ground	NO CHANGE
Base-to-Collector	NO CHANGE

4. Place your fingers across the 220 mfd tuning capacitor. What is the effect?

The frequency decreases slightly due to capacitance caused by the fingers.

5. Substitute the Silicon Transistor, Q7. Does the circuit work? YES

6. Substitute the FET Transistor. Does the circuit work? YES

PHASE SHIFT OSCILLATOR

The theory of operation of the Phase Shift Oscillator is given in the experiment description. The Phase Shift Oscillator is not widely used in electronics circuits because of the difficulty in obtaining a precision frequency output and because of the large number of reactances (capacitors) needed to generate the phase shift. It does, however, illustrate the fundamental concepts of the phase inversion required to sustain oscillation (180^{o} caused by the transistor, then an additional 180^{o} caused by the R.C. network) and the phase shifting properties of the R.C. network itself.

2. Observe the output sine wave signal.
   Does the circuit operate as an oscillator? Yes

FREQUENCY = 580 Hz

3. When the 0.001 mfd capacitor is removed the oscillator may exhibit an oscillation at a very high frequency superimposed on a portion of the normal output waveforms.

5. The 10K pot controlls the output frequency from 580 Hz to 500 Hz. These numbers will vary from trainer to trainer and the students results must be evaluated qualitatively not quantitatively

7. $\tau = RC = 10K \times 0.01 \text{ mfd} = 10\times10^{3} \times 0.01\times10^{-6}$

$= 10^{4} \times 1\times10^{-8} = 10^{-4} = 0.1\text{m sec}$

$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi(0.1\times10^{-3})} = 1590 \text{ Hz}$$

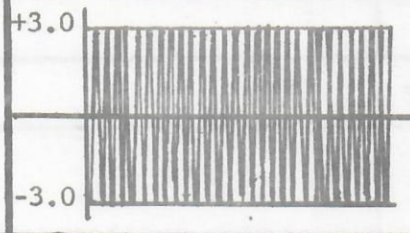
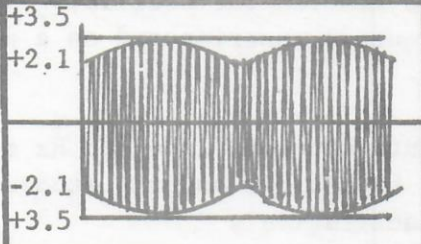
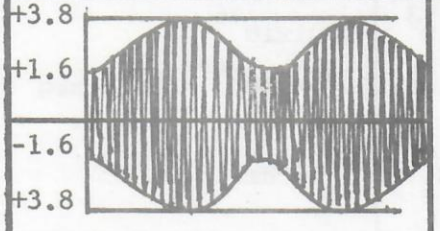
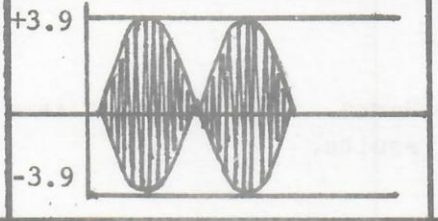
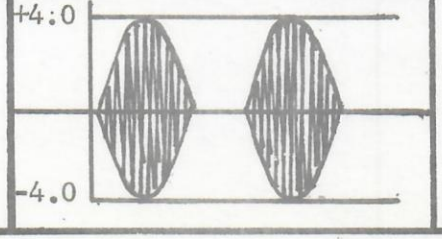
$fp = 1/3\ fc = 530$ Hz

The measured frequency is 580 Hertz. The agreement is within 10% between experimental and theoritical results.

AMPLITUDE MODULATION

A Colpitts Oscillator operating in the A.M. Broadcast Band is Amplitude Modulated by injecting an Audio Signal into the Oscillator Emitter circuit. The Audio Signal changes the Bias point of the Oscillator which results in the output being Amplitude Modulated. In this exercise the mechanism of the modulator is not important, the study of the Amplitude Modulated Waveform is the primary point. The theory is covered very thoroughly in the text of the experiment.

2. Percentage Modulation Table

APPROXIMATE MODULATION	SKETCH WAVEFORM	MEASURE E_{max}	MEASURE E_{min}	CALCULATE % MOD.
0% NO MOD.		6v	6v	$\frac{6 - 6}{6 + 6} \times 100 = 0$
20%		7.0	4.2	$\frac{7 - 4.2}{7 + 4.2} \times 100 =$ $\frac{2.8}{11.2} \times 100 = 25\%$
50%		7.6	3.2	$\frac{7.6 - 3.2}{10.8} \times 100$ $= 40.7\%$
100%		7.8	0	$\frac{7.8 - 0}{7.8 + 0} \times 100=$ $1 \times 100 = 100\%$
OVER-MODULATION		8.0	?	OVER MODULATED

NOTE: When observing the A.M. Waveform with the oscilloscope, the Audio Signal can be used as an external trigger to the scope. This will stabilize the display

A.M. BROADCASTER & A.M. DETECTOR

The A.M. Modulator is modulated with the microphone and the signal is received using an A.M. Receiver. The A.M. Detector and the AGC D.C. signal are also studied.

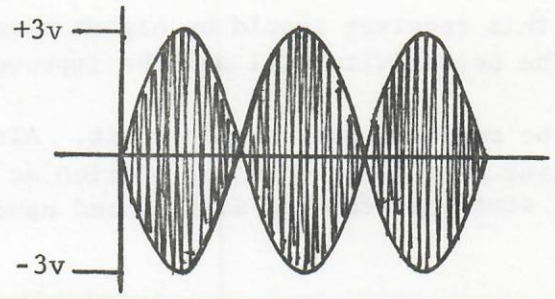
4.

RADIO FREQUENCY (DIAL) = 590 KHz

5. Audio Detected Output

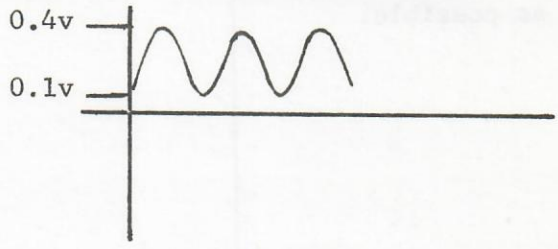
SWITCH B UP

RF SIGNAL



SWITCH B DOWN

AUDIO SIGNAL (Sketch D.C. and Signal Levels)



6. NOTE: The 1 Meg Bias POT must be adjusted to obtain a high percentage of modulation using the microphone. The low voltage output of the microphone makes this necessary.

7. AGC Voltage Measurement

ADJUST R.F. SIGNAL STRENGTH	AGC D.C. VOLTAGE (Meter)
+V1 to maximum	0.15 v
+V1 lower	0.10 v
+V1 medium	0.05 v
+V1 very low	0.02 v

RADIO DETECTOR

This is the first exposure of the student to the Radio Receiver. Two versions are built and tested. The first is the Crystal Set, the second is an improved version of a crystal set using a transistor to offer a higher impedance to the input tuned circuit for improved selectivity. Note that the base-emitter junction diode serves as the detector diode in this circuit.

2. The stations received using the "Crystal Set" will be limited to the strongest stations in the local area. Also, there will be noted some overlap in the tuning causing two stations to be received simultaneously, if two local stations are near each other in frequency.

4. The volume output of this receiver should be higher because of the current gain of the transistor. The selectivity will also be improved.

5. More stations should be received with this circuit. Also, the selectivity or ability for the receiver to receive only one station at a time should be improved. The actual stations received will depend upon particular stations local to the area.

NOTE: The length and height of the receiving antenna is very important to the performance of this experiment. Use as long an antenna at as great a height as possible.

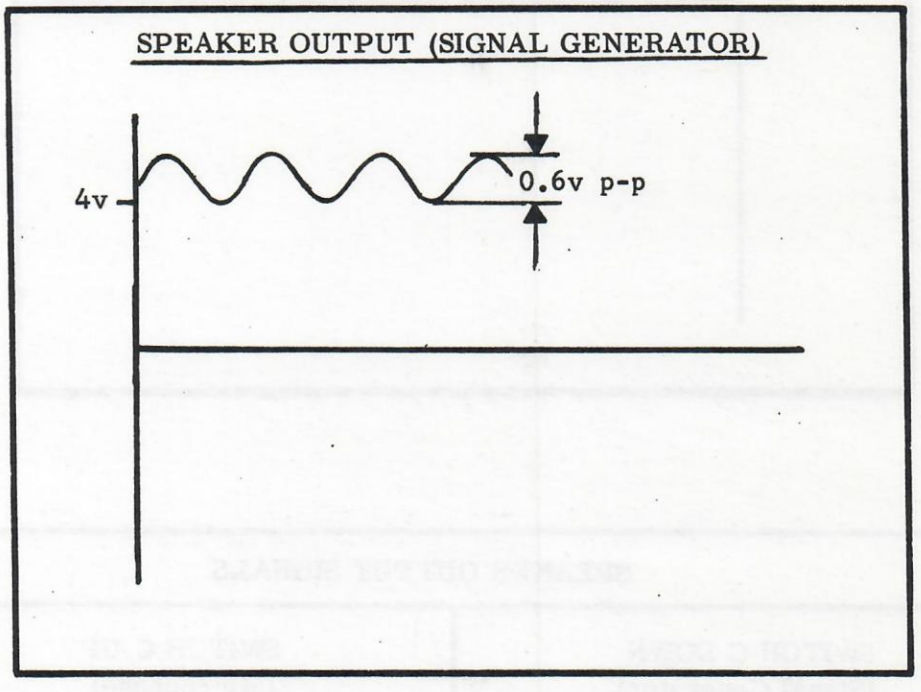
AUDIO OUTPUT AMPLIFIER

Common Emitter and Common Collector Audio Amplifiers are tested with signal generator and microphone inputs.

3. The input voltage level measured at the wiper of the 10K POT is 0.2 volts peak to peak at maximum input. For this input the output voltage is 0.6 volts peak to peak.

V_{input} (Max) peak to peak = 0.2 volts

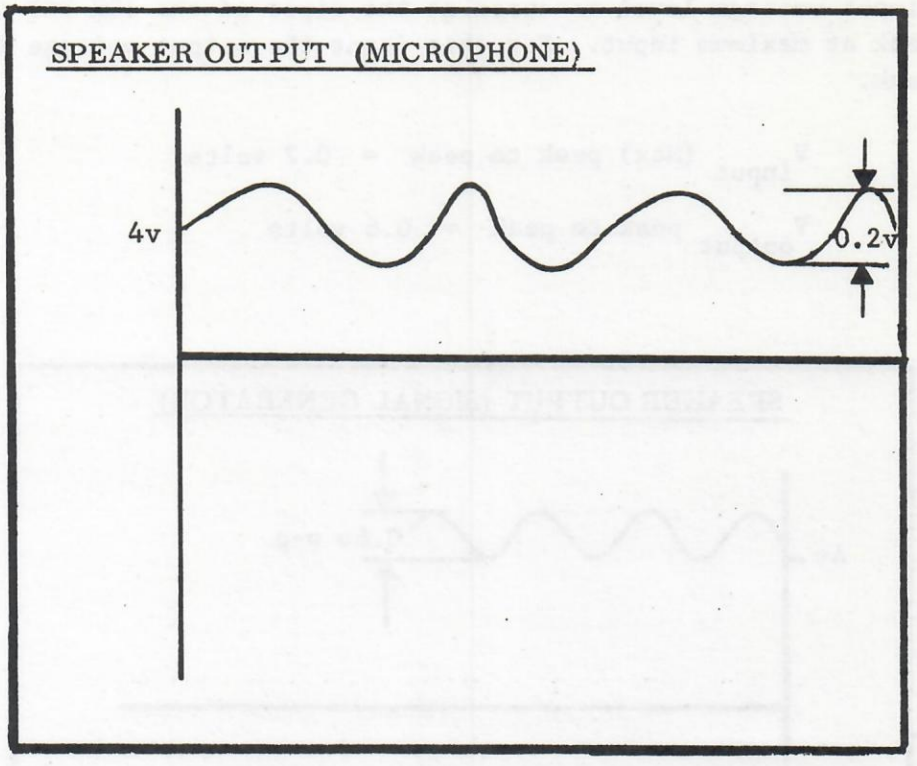
V_{output} peak to peak = 0.6 volts



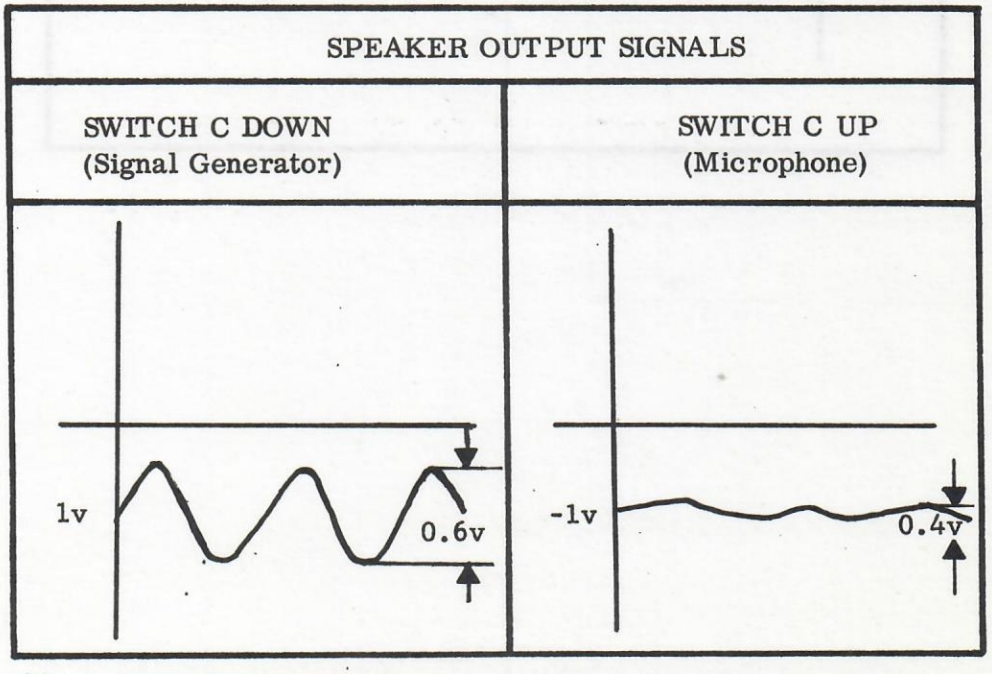
Note: The peak to peak signal voltage may be measured by placing the oscilloscope input on A.C. and expanding the vertical voltage scale.

AUDIO OUTPUT AMPLIFIER

5. The sound from the microphone is low but it can be heard by a second person near the speaker.

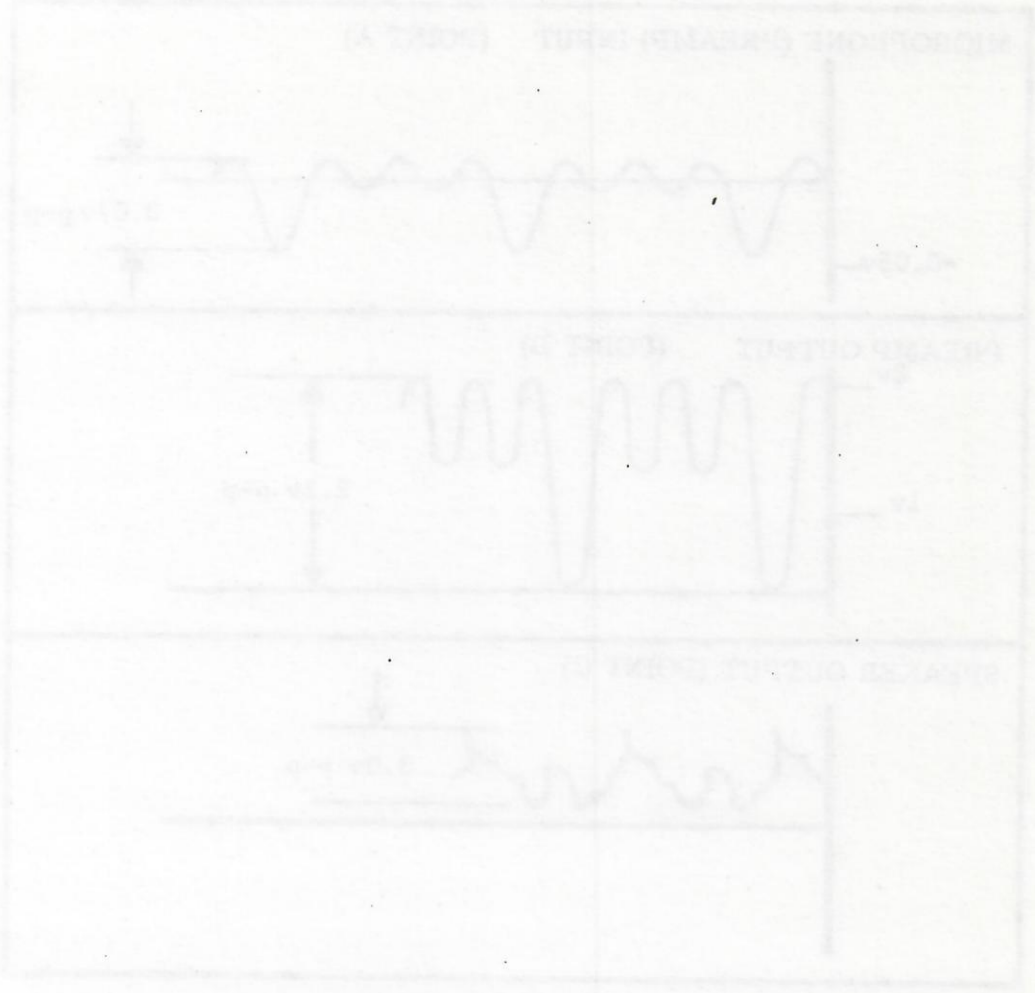


7.



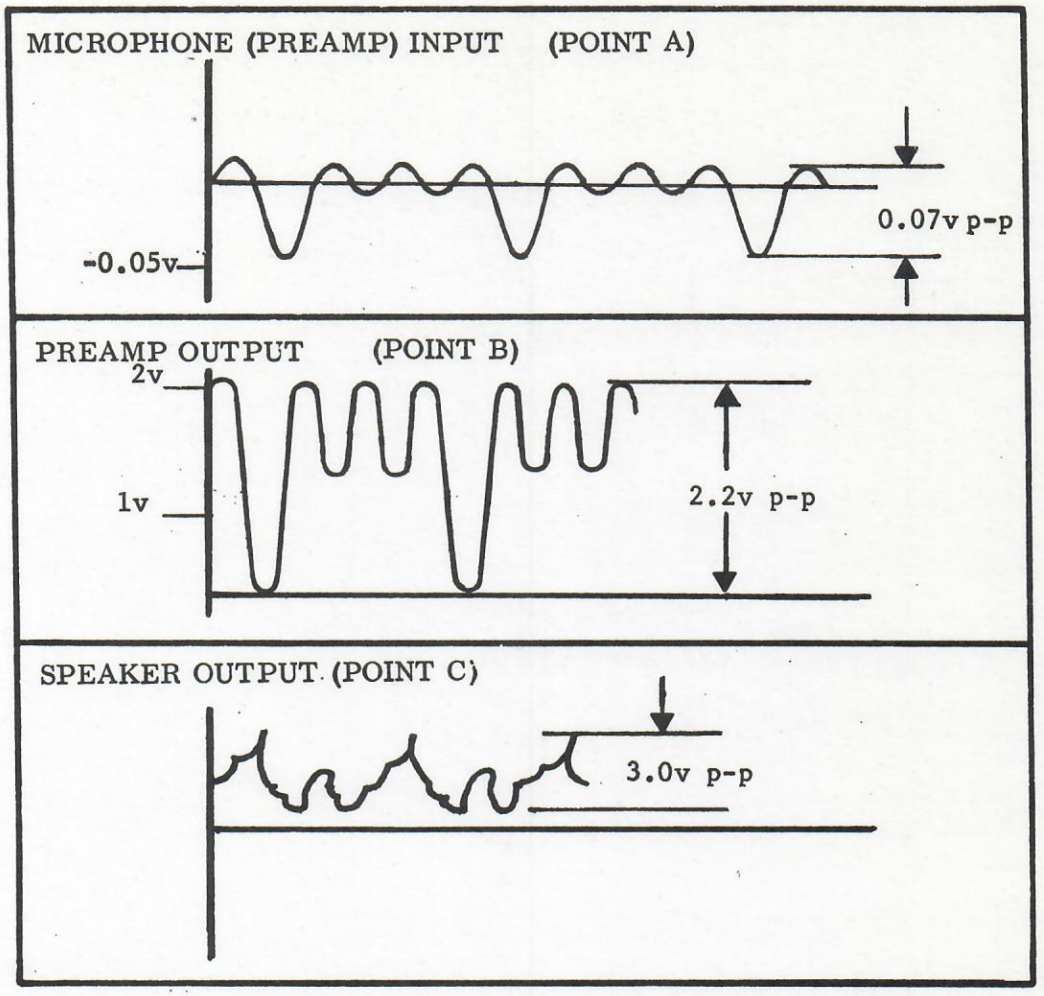
AUDIO OUTPUT AMPLIFIER

8. These amplifiers are not good microphone amplifiers because they do not have high GAIN. The microphone output must be amplified to a higher voltage level before using the signal to drive a speaker.



AUDIO PREAMPLIFIER

This experiment solves the problem encountered in Experiment No. 9. The microphone output voltage is preamplified with a transistor stage before the speaker driver. Both the preamplifier and the speaker driver stages are common emitter amplifiers. The 10K collector resistor in the preamplifier stage gives good Voltage Gain. The second stage drives the speaker.



$$\text{PREAMP VOLTAGE GAIN} = \frac{\text{output voltage (B)}}{\text{input voltage (A)}} = \frac{2.2}{0.07} = 31.4$$

PRE-AMP GAIN = 31.4

3. The speaker output is much louder with the preamplifier circuit. The voice can be heard very clearly.

AUDIO PREAMPLIFIER

4. Calculation Input Power

$$\text{INPUT POWER} = \frac{V^2}{R} = \frac{(0.07)^2}{2000(2.8)}2 = 3.1 \times 10^{-7} \text{ watts}$$

5. Calculation of Loudspeaker Power

$$\text{LOUDSPEAKER POWER} = \frac{3^2}{8(2.8)}2 = 0.14 \text{ w}$$

6. Power Gain

$$\text{POWER GAIN} = \frac{0.14}{3.1 \times 10^{-7}} = 0.45 \times 10^{7} = 4.5 \times 10^{6}$$

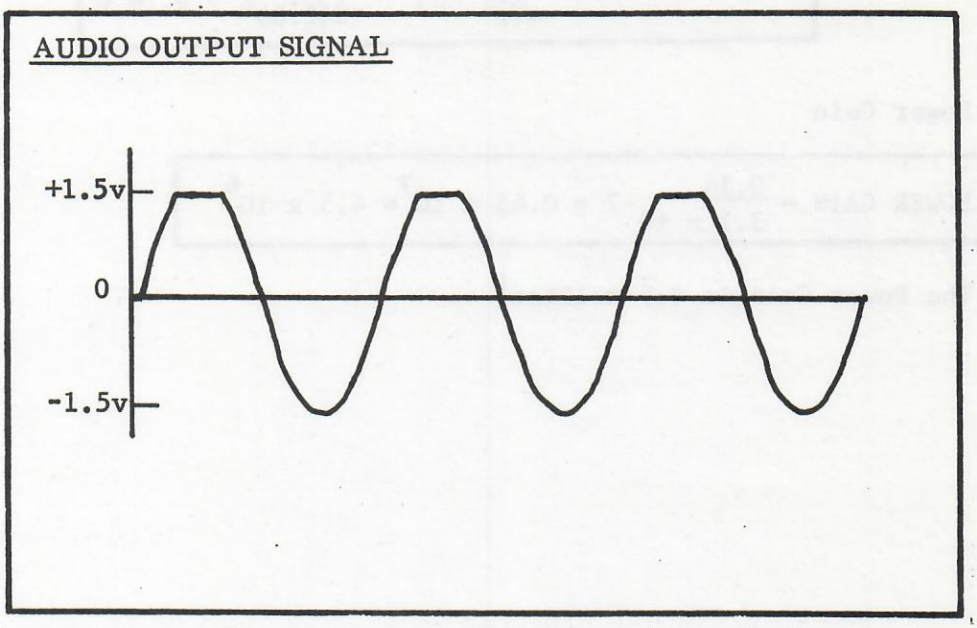
The Power Gain is 4.5 million!

COMPLEMENTARY AUDIO AMPLIFIER

This is a very sensitive audio amplifier with a high gain. At the highest gain the amplifier can experience audio "feedback" causing the system to "squeal". This can be stopped by moving the microphone away from the speaker.

2. BIAS POT SETTING = 50K ohms

3. The volume from this system is quite loud. It is a much better amplifier than the circuits in Experiments 9 and 10 because it has greater sensitivity and output power. There is a noticable power supply hum in the speaker. The hum measures 0.15 volts peak-to-peak at full volume. The output voltage when speaking into the microphone with the amplifier set at full volume is 3 volts peak-to-peak.



4. When the microphone is placed near the loudspeaker the system "squeals". This is caused by the audio feedback from the loudspeaker into the microphone.

5. Output Power measurement is performed by measuring the output voltage and applying the Power Formula.

$$\text{POWER OUTPUT} = \frac{(V_{out})^2 \text{ peak to peak}}{8 \times (2.8)^2} = 140 \times 10^{-3} = 140 \text{ milliwatts}$$

For this amplifier the power output is 140 milliwatts.

Measurement of the Frequency Response is performed by connecting a calibrated audio signal generator in place of the microphone. The audio input from the generator is set to produce an undistorted output signal and this input level is recorded. The audio generator frequency is then set a various points and the input level is adjusted to the level previously recorded, then the output voltage at this frequency is recorded. The results may be plotted as Output Voltage versus Frequency or as Power Gain versus Frequency.

AM RADIO RECEIVER AND VARACTOR DIODE

A simple tuned circuit radio receiver with an audio driver is fabricated and the local radio stations are received and logged. Then the fixed capacitor in the tuned circuit is replaced with a Varactor Diode network to act as a variable capacitor and the radio is tuned using the Varactor Diode.

The Varactor Diode is a diode used as a Voltage Variable Capacitor. When the Varactor Diode is reverse biased, the Depletion Region (Region in the Semiconductor Diode where there are no charge carriers) acts as a capacitor. The larger the reverse bias, the smaller the diode capacitance because the depth of the depletion region increases.

$$C = \frac{\in A}{d}$$

$\in$ = Constant

A = Area of the Capacitor Plates

d = Distance between Capacitor Plates.

2. The radio stations received depend upon the strength of the radio signal in the local area.

3. In the New York area we received four stations with a good antenna attached to the radio.

4. The stations overlapped, indicating that the Selectivity between stations was poor.

5. The volume was comfortable for listening.

7. Using the Varactor Diode as the tuning element the tuning range was about one-third that of the tuning slug. The Varactor tuning, however, works perfectly.

NOTE: By using the Varactor Diode as a tuning capacitor the receiver may be tuned electronically. This requires no moving parts and allows for "electronic tuning" based on signal strength or any other electronic signal.

FREQUENCY MODULATION

An FM Generator is tested. Special attention should be paid to the fact that the frequency deviation of the output signal depends upon the Amplitude of the modulating signal, not the frequency.

2. Output Waveform Measurements

OSCILLOSCOPE MEASUREMENTS	
CYCLES MEASURED	6
High Frequency (TIME)	9.2 microseconds
Low Frequency (TIME)	9.4 microseconds

CALCULATIONS
f_{HIGH} = 652 KHz
f_{LOW} = 638 KHz
$f_{CARRIER}$ = 645 KHz

3.

f_{AUDIO} = 2 KHz

4. Frequency Deviation

$$\text{FREQUENCY DEVIATION} = (f_{HIGH} - f_{CARRIER})$$

FREQUENCY DEVIATION = 652KHz - 645KHz = 7 KHz

$$\text{MODULATION INDEX} = \frac{75\ \text{KHz}}{f_{AUDIO}} = \frac{75}{2}$$

MODULATION INDEX = 37.5

5. When the microphone is used the output signal changes frequency in response to the voice. A substantial frequency variation is caused by speaking into the microphone.

NOTE: When using the microphone it may be necessary to increase the number of cycles viewed on the oscilloscope to easily see the frequency variation. This is caused by the small microphone voltage output. Users with the newest experiment manual with the microphone amplifier circuit will get higher modulation when speaking into the microphone.

AUDIO TRANSFORMER

The ratio of input voltage to output voltage for the transformer windings are measured and recorded.

2. & 3.

WINDING IMPEDANCE	IMPEDANCE RATIO (N^2)	TURNS RATIO $N = \sqrt{N^2}$	STEP 2 READ VOLTAGE	STEP 3 CALCULATE $\frac{\text{INPUT}}{\text{OUTPUT}} = N$
3,000 OHMS PINS ④ ⑤	INPUT	____	INPUT POINT A ④ 1.0	____
*500 OHMS PINS ① ③	$\frac{3000}{500} = 6$	2.45	POINT B ① 0.43	$\frac{A}{B} = 2.32$
250 OHMS PINS ② ③	$\frac{3000}{125} = 24$	4.89	POINT C ② 0.2	$\frac{A}{C} = 4.76$
8 OHMS PINS ⑥ ⑦	$\frac{3000}{8} = 375$	19.36	POINT D ⑥ 0.052	$\frac{A}{D} = 19.2$

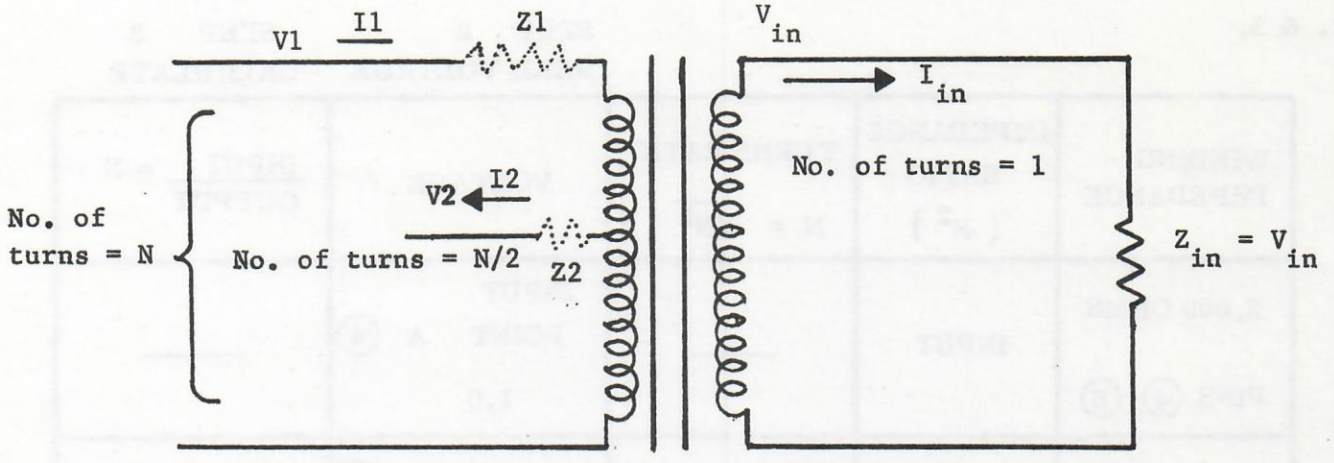
4. All the turns ratios agree very closely.

*Note that the center tap on the 500 ohm secondary winding has an impedance of 125 ohms. The center tap will be $\frac{1}{4}$ the impedance of the entire winding because the impedance varies as the square of the turns ratio.

**Note: Older versions of the Audio Transformer used a 1000 ohm centertapped transformer.

AUDIO TRANSFORMER

For a center tapped transformer we can make the following schematic:



Z1 & Z2 are the impedances of the secondary winding caused by the Z_{in} input impedance connected to the primary.

$$V1 = N\,V_{in}$$

$$I1 = \frac{I_{in}}{N}$$

$$Z1 = \frac{V1}{I1} = \frac{NV_{in}}{\frac{I_{in}}{N}} = N^2\,\frac{V_{in}}{I_{in}} = N^2 Z_{in}$$

$$V2 = \frac{V_{in}\,N}{2}$$

$$I2 = \frac{I_{in}}{N/2}$$

$$Z2 = \frac{\frac{V_{in}\,N/2}{I_{in}}}{\frac{N/2}{}} = \frac{V_{in}\,N^2}{I_{in}\,4} = \frac{Z_{in}\,N^2}{4} = \frac{Z1}{4}$$

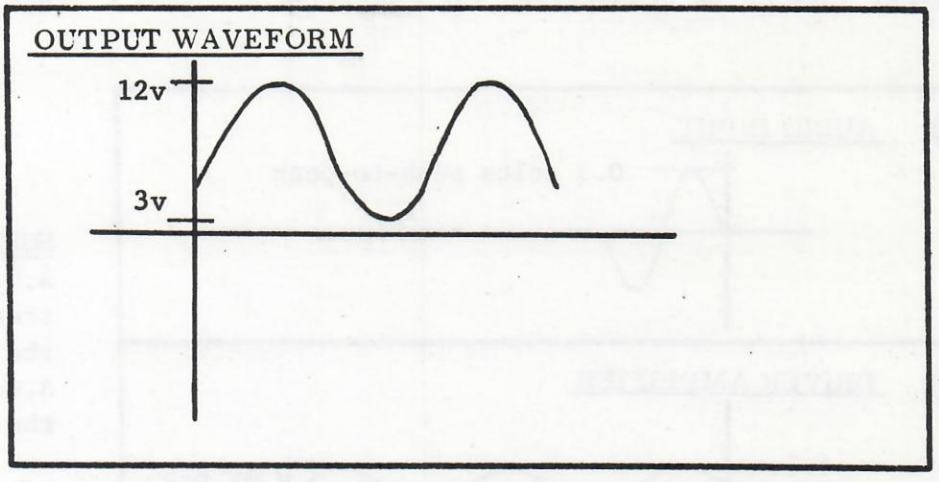
$$Z2 = \frac{Z1}{4}$$

Note that the impedance of the center tapped winding is ¼ the impedance of the whole winding.

SINGLE-ENDED TRANSFORMER AMPLIFIER

The Audio Transformer is used to "match" the 8 ohm speaker impedance to the transistor amplifier output impedance.

2.



R_f = 100K

3. With the Microphone input the 10K POT may be advanced to the full volume position.

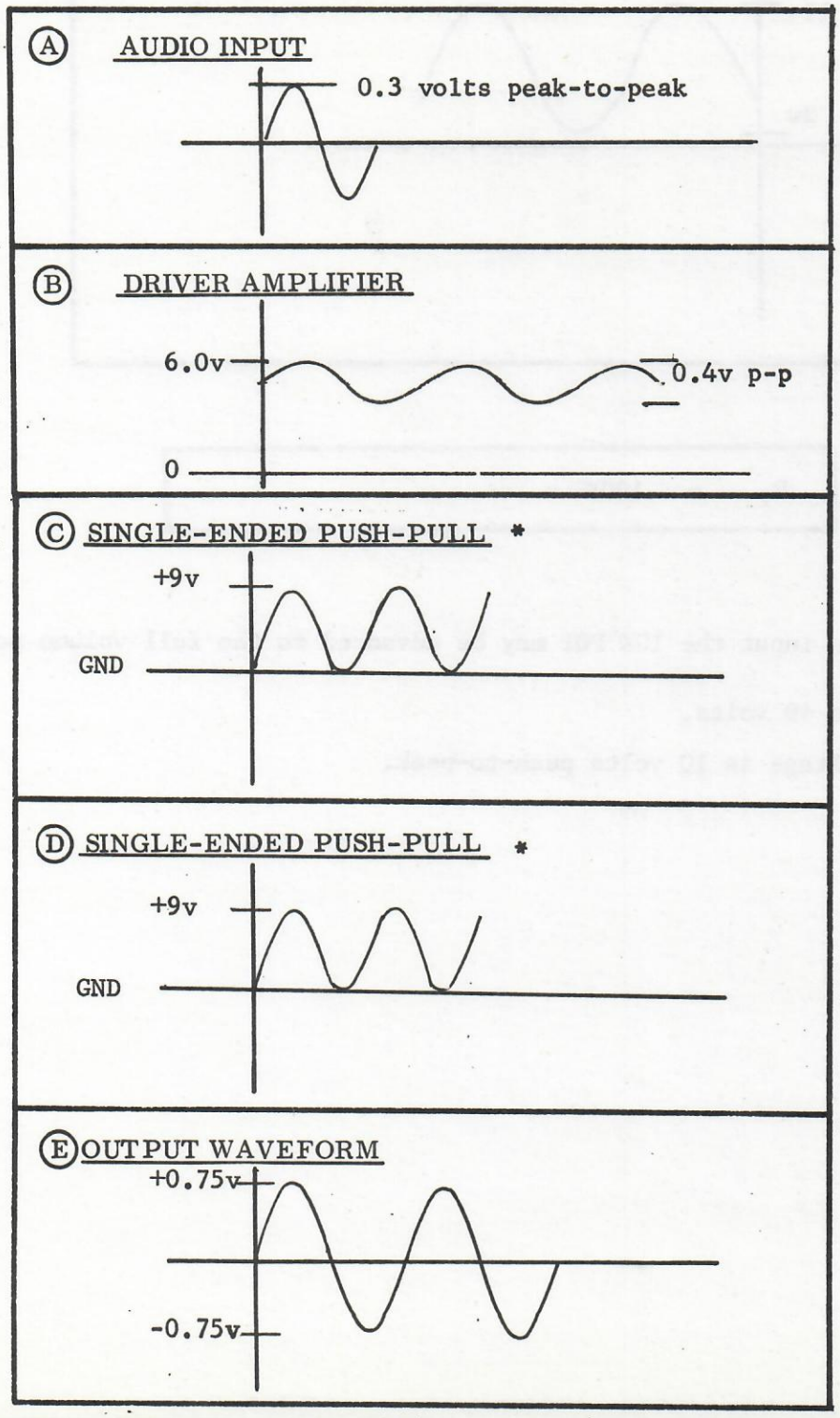
   The D.C. voltage is +9 volts.

   The A.C. Speech Voltage is 10 volts peak-to-peak.

PUSH-PULL AUDIO AMPLIFIER

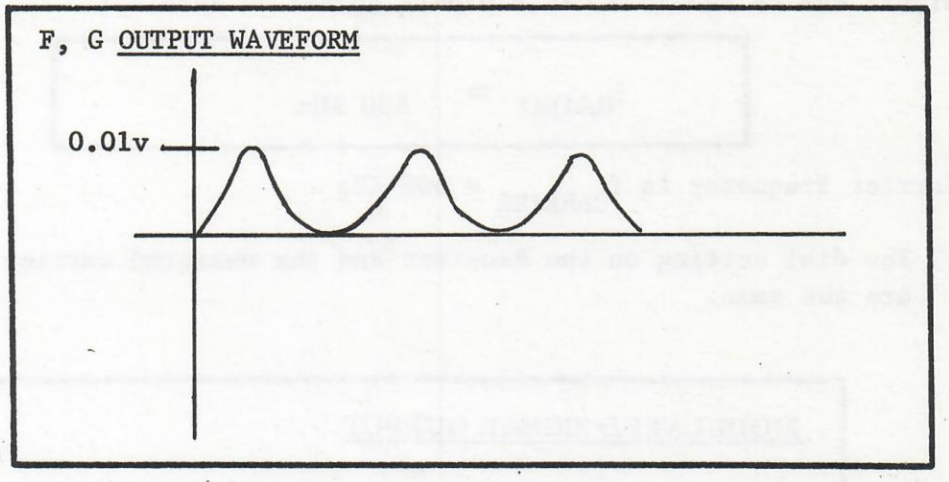
This circuit is a Push-Pull Power Amplifier. The output transistors Q4 and Q5 are operating as class C amplifiers. They are only on for ½ the input cycle. The 100 ohm resistor in the base of Q4 in the schematic is not typical of this type of amplifier. It is wired into this experimental circuit to allow the measurement of base current into Q4 to demonstrate the operation of class C stage.

4.



NOTE: The peak-to-peak A.C. voltage may be studied closely by using the oscilloscope on the A.C. scale and expanding the Vertical deflection.

PUSH-PULL AUDIO AMPLIFIER



NOTE: If 10K volume POT is increased this waveform will look exactly like a halfwave rectified signal. The current flows only during ½ of the input signal waveform. This indicates class C amplifier operation where the transistor is OFF when there is no input signal and the transistor is ON only during ½ cycle when an Input Signal is present.

AM TRANSMITTER, COLLECTOR MODULATION

The theory is covered in the body of the experiment.

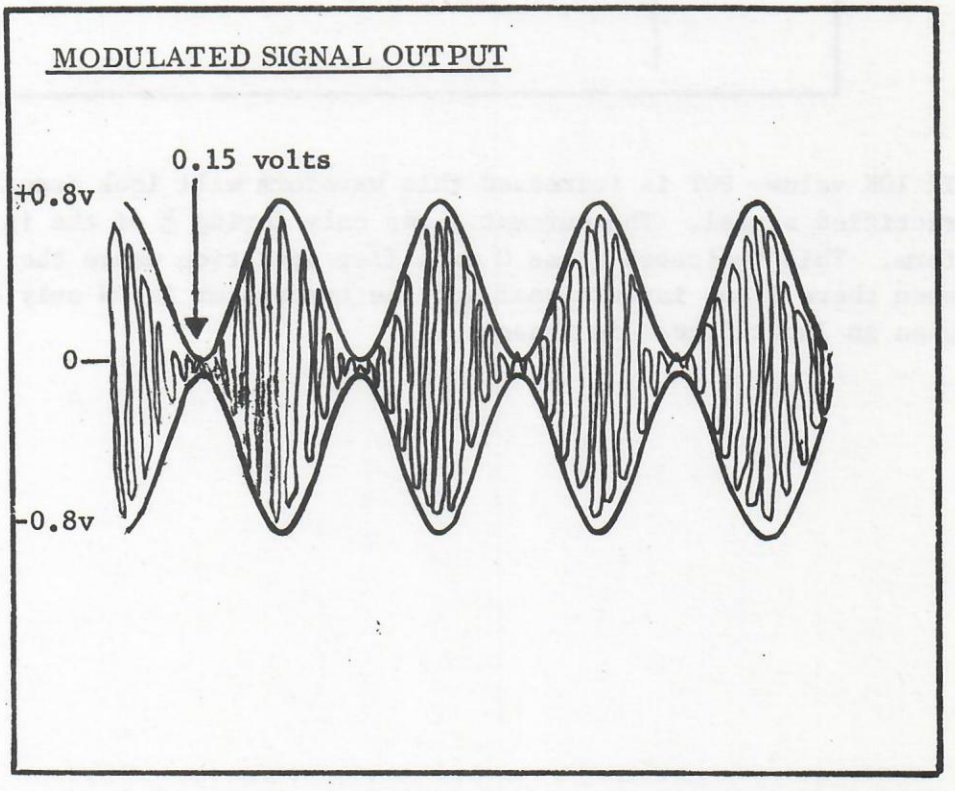
3. The signal can be received clearly on a normal AM Receiver

f_{RADIO} = 600 KHz

4. The Carrier frequency is $f_{CARRIER}$ = 600 KHz

   Note: The dial setting on the Receiver and the measured carrier frequency are the same.

5.



6. Calculation of % modulation

$$\%M = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100\% = \frac{1.6 - 0.15}{1.6 + 0.15} \times 100\% = 82.8\%$$

% MODULATION = 82.8%

7. The voice modulated signal can be received and clearly understood with an AM Radio. The range of the transmitter, however, is very limited and the receiver must be placed close to the transmitting antenna.

SUPERHETRODYNE RECEIVER AND LOCAL OSCILLATOR

The Local Oscillator is a design which is typical of that found in AM broadcast receivers. The transformer couples the collector signal back to the emitter circuit to generate oscillation. The frequency of oscillation is determined by the setting of the variable capacitor on the Superhet Card.

The transformers and the coils on the Superhet Card are adjusted at the factory. If possible do not change the settings of the coils.

2. Measurement of Tuning Range of Local Oscillator

T_{LOWEST} = 1.2 microseconds

f_{LOWEST}

$$f_{LOWEST} = \frac{1}{T} = \frac{1}{1.2 \times 10^{-6}} = 833 \text{ KHz}$$

T

$T_{HIGHEST}$ = 0.5 microseconds

$$f_{HIGHEST} = \frac{1}{T} = \frac{1}{0.5 \times 10^{-6}} = 2 \text{ MHz}$$

3. Calculation of Receiver Tuning Range

f_{LOW}	= 833KHz - 455KHz = 378 KHz
f_{HIGH}	= 2000KHz - 455KHz = 1545 KHz

4. This tuning range exceeds the AM band at the LOW frequency and will tune almost to the high end of 1600 KHz.

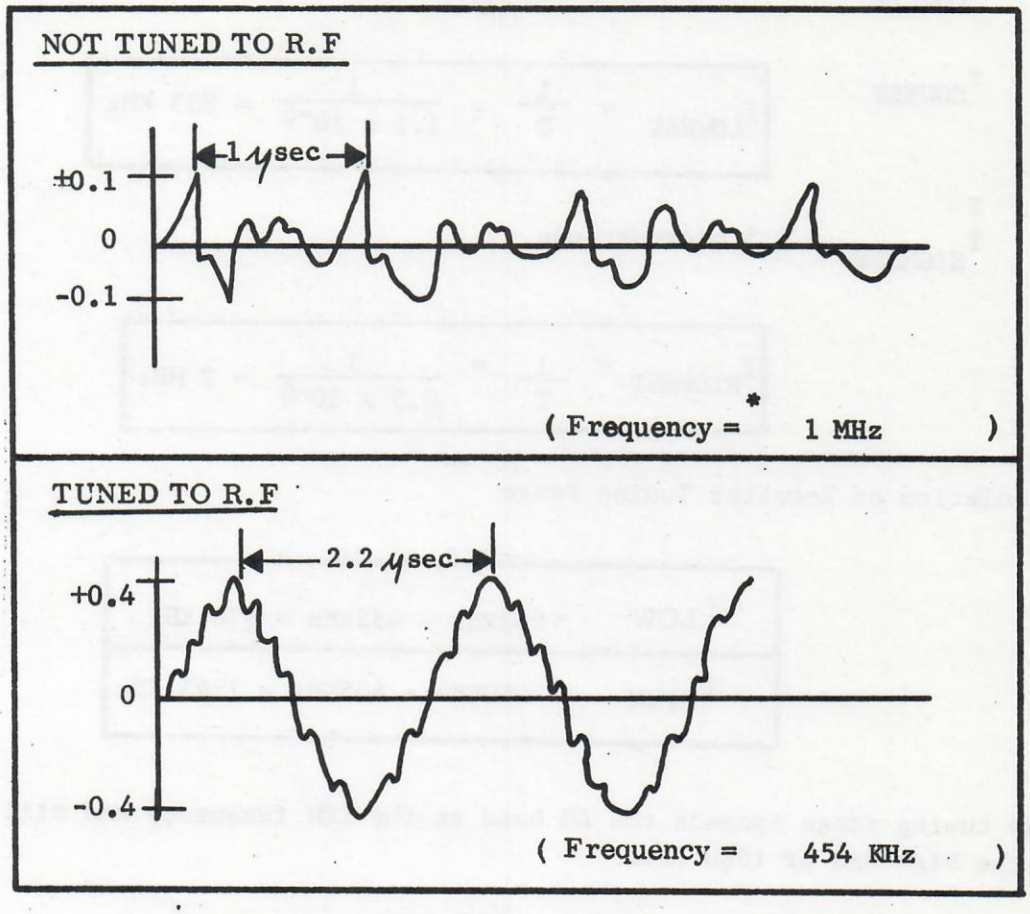
MIXER-CONVERTER

This is the next step in the building blocks leading to the Superhetrodyne Receiver. The student measures the output signal of the Mixer-Converter circuit when the local oscillator is to the correct input R.F. Generator frequency and when detuned from the R.F. Signal input. When the local oscillator is tuned to the correct frequency the output voltage is at a maximum and the output frequency is 455 KHz.

The I.F. Transformers are adjusted at the factory. Avoid changing the adjustment.

2. Sketch of Output Waveforms

WAVEFORMS



3. When the Receiver is not tuned to the R.F. "station", does the output frequency vary and correspond to the local oscillator?

   When the Receiver is not tuned to the R.F. station, conversion still takes place, the output, however, is very low because the I.F. Transformers are tuned to pass only 455 KHz.

4. When the Receiver is tuned, what is the frequency at the I.F. frequency?

   This 454 or actually 455 KHz signal is the "tuned" frequency because it is the frequency "passed" by the tuned I.F. transformers.

MIXER-CONVERTER

5. What are the output voltage levels when the receiver is out of tune, and when tuned?

VOLTAGE (NOT TUNED)	=	0.2v peak-to-peak
VOLTAGE (TUNED)	=	0.8v peak-to-peak

VARIABLE GAIN AMPLIFIER & AGC

This experiment demonstrates the method of controlling the gain of a common emitter amplifier by changing the bias point of the amplifier.

This demonstrates the operation of the Automatic Gain Control (AGC) found in Radio Receivers.

The variation in gain with change in bias is due to the variation in the base resistance of a transistor with DC Collector Current. Since the base resistance of a transistor is directly in series with the base emitter circuit, a variation in the base resistance will cause a change in the amount of base current which will flow for a given input voltage. The base resistance for a transistor is given by:

$$r_{eb} = \frac{25B}{I_c(ma)}$$

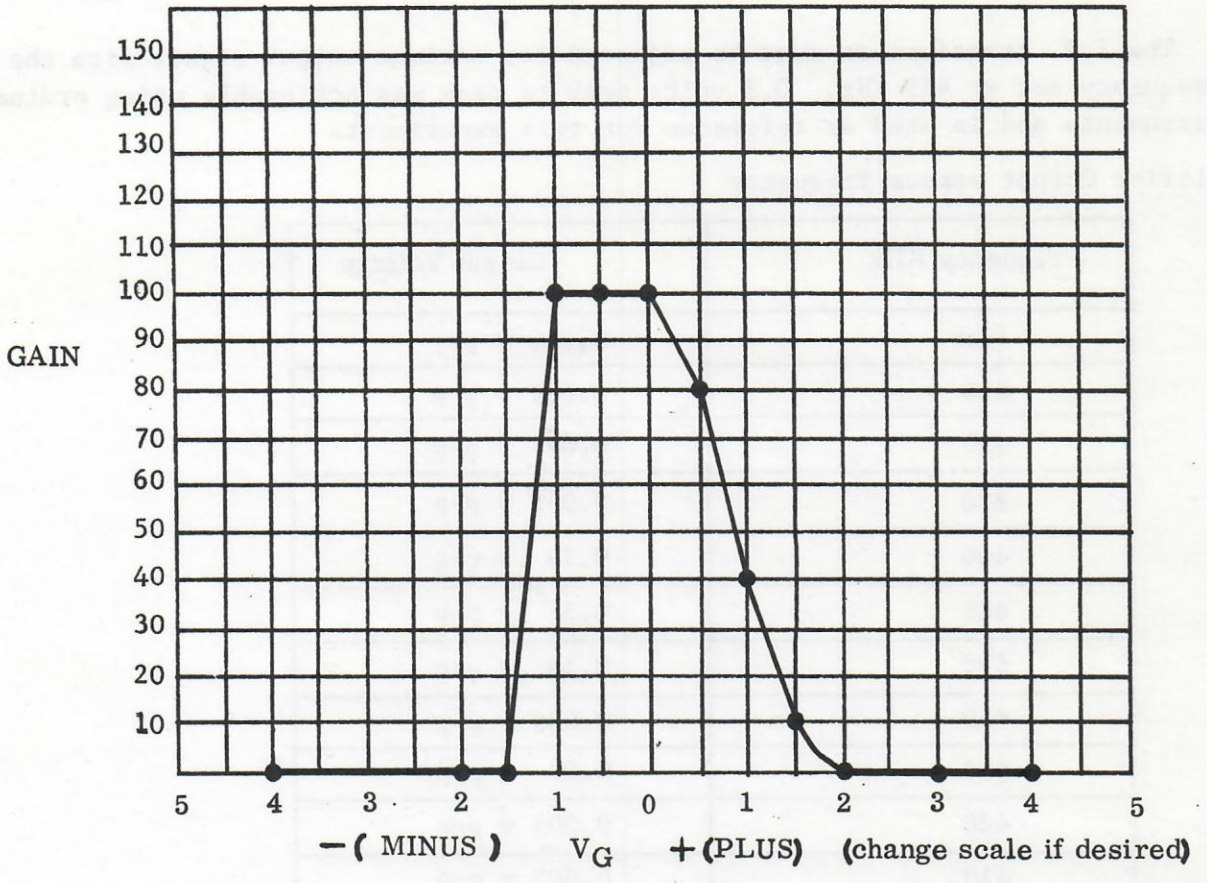
When the Bias Voltage is adjusted to increase the DC Collector Current, the base resistance will decrease causing the gain to increase.

3. Tabulation of Input and Output Voltages for each Gain Voltage.

VOLTAGE (PEAK TO PEAK)		GAIN CONTROL	CALCULATE
INPUT (V_{IN}) SWITCH A DOWN	OUTPUT (V_{OUT}) SWITCH A UP	D.C., V_G VOLTAGE	GAIN= $\frac{V_{OUT}}{V_{IN}}$ x 100
1.0	1.0	0	100
1.0	1.05	-0.5	100
1.0	1.0	-1.0	100
1.0	0	-1.5	0
1.0	0	-2	0
1.0	0	-4	0
1.0	0	-6	0
1.0	0.8	+0.5	80
1.0	0.07	+1	40
1.0	0	+1.5	7
1.0	0	+2.0	0
1.0	0	+3	0
1.0	0	+4	0

VARIABLE GAIN AMPLIFIER & AGC

5. Graph of the Gain versus V_G



6. Does the Gain of the amplifier vary with the bias voltage? YES

8. At what Voltage, V_G, is the gain at a maximum? What is the maximum gain?

GAIN (maximum) = 100
V_G (setting for max. gain) = 0

Note from the curve in step 5 that the Amplifier Gain decreases sharply as the V_G increases from 0 volts to +1.5 volts. Looking at the Schematic Diagram, Figure 20-1, we see that this increasing voltage at V_c causes the transistor Base Voltage to become more Positive. The more positive base potential causes the DC Base Current to decrease. As the DC Base Current decreases, the DC Collector Current decreases proportionally, causing the r_{eb} Base Resistance to increase. The increased base resistance will reduce the base current that can be generated by an input voltage and will therefore, cause the amplifier gain to decrease .

I.F. TUNED AMPLIFIER

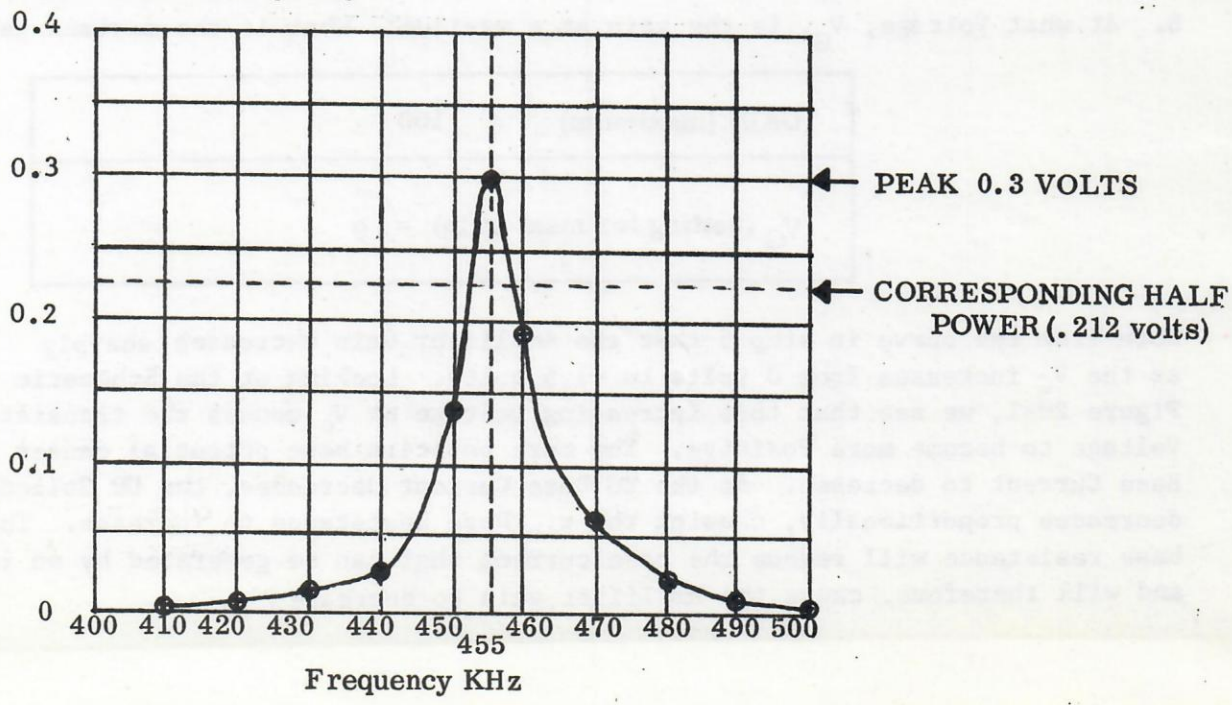
This amplifier circuit has a tuned transformer input and output. The circuit is typical of the I.F. amplifier used in Superhetrodyne Receivers. The Gain versus Frequency curve of this amplifier will be measured and the amplifier Gain will be controlled by changing the Bias Voltage on the transistor. This is introductory to AGC operation.

4. - 7. The I.F. transformers must be adjusted for maximum output signal with the input frequency set at 455 KHz. 0.3 volts peak to peak was achievable using ordinary test instruments and is used as reference for this experiment.

8. Amplifier Output versus Frequency

Frequency KHz	Output Voltage
500	0.008 v p-p
490	0.011 v p-p
480	0.021 v p-p
470	0.062 v p-p
460	0.19 v p-p
455	0.3 v p-p
450	0.14 v p-p
440	0.029 v p-p
430	0.01 v p-p
420	0.005 v p-p
410	0.003 v p-p

9. Plot of Output versus Frequency



I.F. TUNED AMPLIFIER

10. From the curve of step 8 the half power frequencies are 451 and 459 KHz

The Bandwidth is given by:

I.F. BANDWIDTH = 459 - 451 = 8 KHz

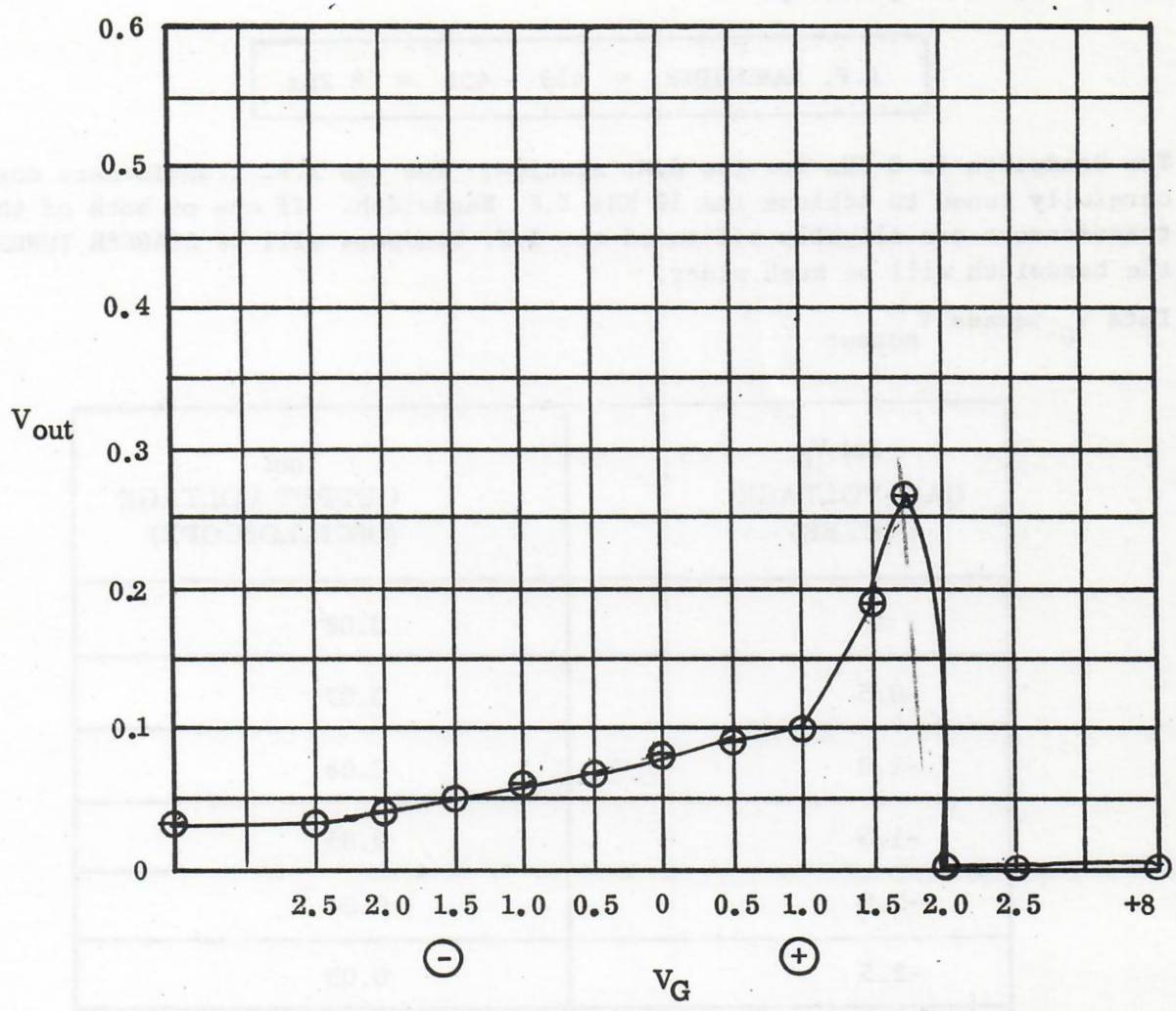
11. The Bandwidth is 8 KHz for the A.M. station. The two I.F. transformers must be carefully tuned to achieve the 10 KHz I.F. Bandwidth. If one or both of the transformers are slightly off tuned the I.F. bandpass will be STAGGER TUNED and the bandwidth will be much wider.

14. Data V_G versus V_{output}

Set V_G GAIN VOLTAGE (METER)	V_{out} OUTPUT VOLTAGE (OSCILLOSCOPE)
0	0.08
-0.5	0.07
-1.0	0.06
-1.5	0.05
-2.0	0.04
-2.5	0.03
-maximum (-2.8)	0.03
+0.5	0.08
+1.0	0.10
+1.5	0.18
+2.0	0.00
+8.0	0.00
V_e Max Gain (+1.6)	0.32

I.F. TUNED AMPLIFIER

15. Plot of Bias Voltage versus Output Voltage



RECEIVER ALIGNMENT

The Superhetrodyne Receiver is built and the coils and Local Oscillator are tuned for proper operation in the A.M. Broadcast Band.

Note: The transformer coils and the oscillator coil mounted on the Superhet Card are the type used in transistor radios and are not overly rugged. The student must be instructed to be careful in making the alignment adjustments to prevent stripping or breaking the transformer cores.

During the intial stages of the alignment procedure the R.F. Generator output amplitude will probably be set at maximum. This will be necessary to obtain a readable waveform on the oscilloscope.

As the stages are adjusted this will result in saturation and clipping at the output and the R.F. Generator output must be reduced to enable the technician to see the effects of his adjustments.

AM RADIO & AMPLIFIER

The A.M. Superhetrodyne Receiver is now tested. The output is connected to an audio amplifier and the output is heard via a loudspeaker.

The antenna used will greatly affect the receiver performance, use a long antenna, outside the building and as high as possible.

The stations received and recorded in the table of the experiment will vary with the locality, however, in most areas, several radio stations should be received.

RECEIVER TROUBLESHOOTING

This experiment affords the student an opportunity to try to find a fault in a Radio Receiver. After the student has built and tested the receiver and has verified that it is working the instructor will insert a trouble into the receiver by removing a wire or changing a connection. Then the student will test the receiver, find the trouble and report to the instructor.

It is important that the student perform his troubleshooting by making electrical measurements and not by mechanically verifying the wiring. The students test report should show the incorrect waveform or voltage measurement and the correct waveform or voltage.

FILTER RESPONSE & DECIBELS

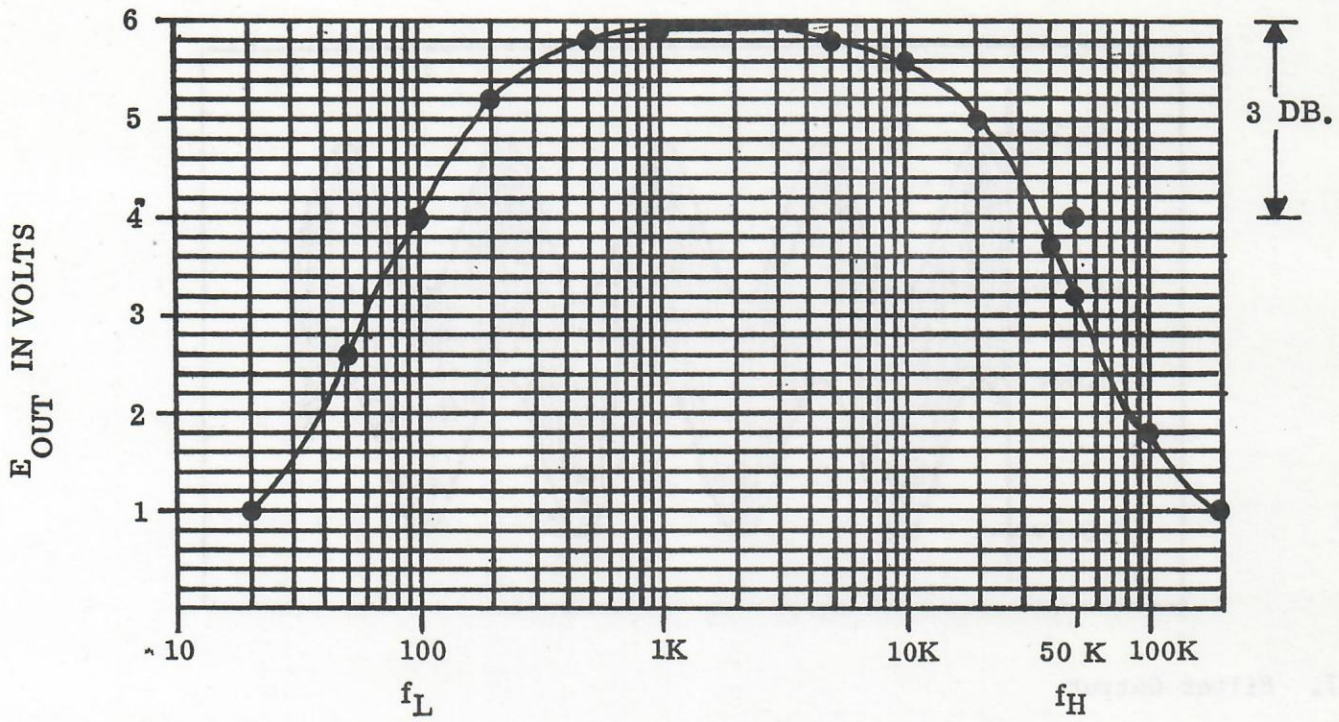
The student will use a log frequency scale and a Decibel scale. This may require some review. The basic theory is covered in the experiment.

5.

FREQUENCY	OUTPUT VOLTAGE (Peak - to - Peak)
20 Hz	1.0 v p-p
50 Hz	2.6 v p-p
100 Hz	4.0 v p-p
200 Hz	5.2 v p-p
500 Hz	5.8 v p-p
1000 Hz	5.9 v p-p
2000 Hz	5.9 v p-p
5000 Hz	5.8 v p-p
10 KHz	5.6 v p-p
20 KHz	5.0 v p-p
40 KHz	3.7 v p-p
50 KHz	3.2 v p-p
100 KHz	1.8 v p-p
200 KHz	1.0 v p-p

FILTER RESPONSE & DECIBELS

6. Plot of Data



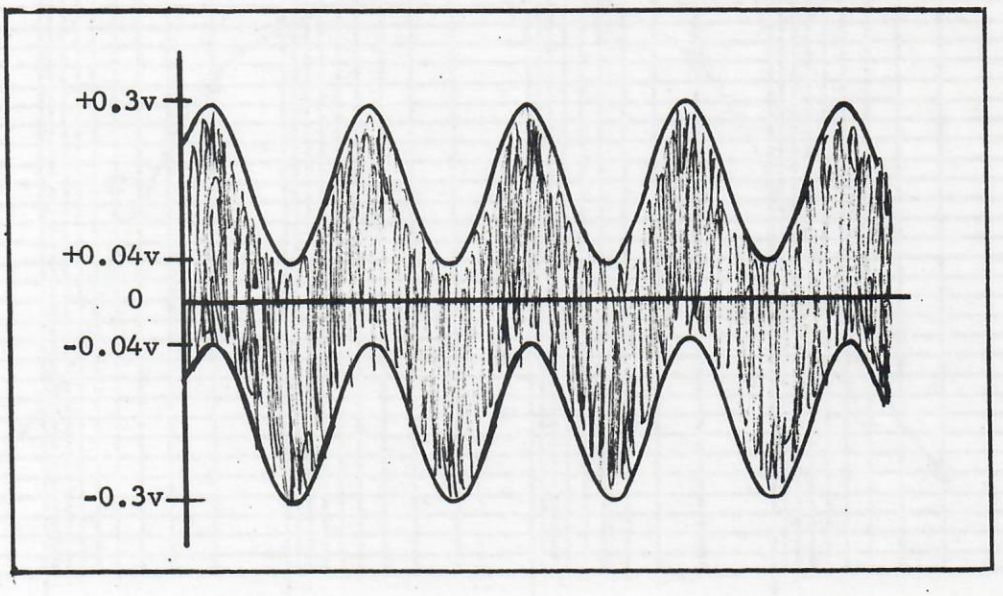
7. How do the actual results compare with the anticipated results?

The low frequency response is exactly as predicted. The high frequency response falls off at a lower frequency than expected due to strong capacitance in the interconnection leads.

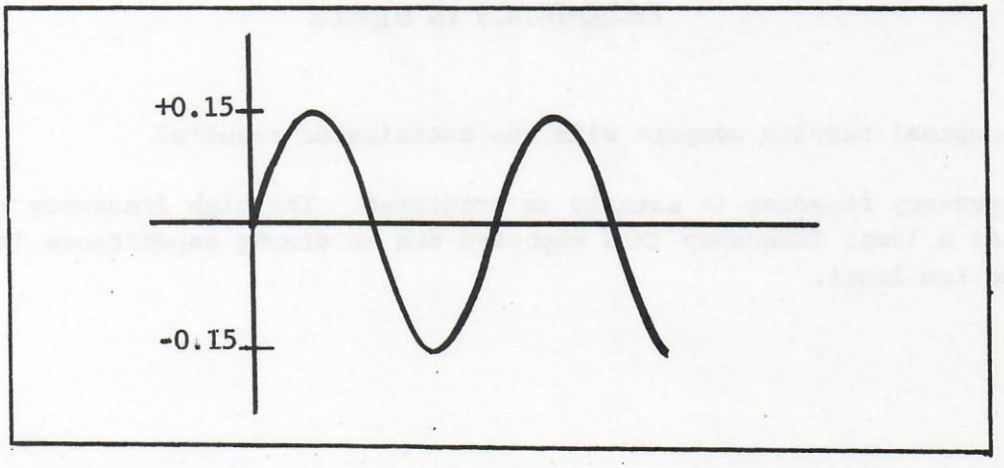
FREQUENCY TRAP FILTERS

A Trap Filter is used to remove the high frequency component of a signal that consists of a high and low frequency signal added together. This type of circuit is used in demultiplexing or separating two signals which are carried on the same channel.

5.



7. Filter Output



Virtually no R.F. signal can be seen on the audio output.

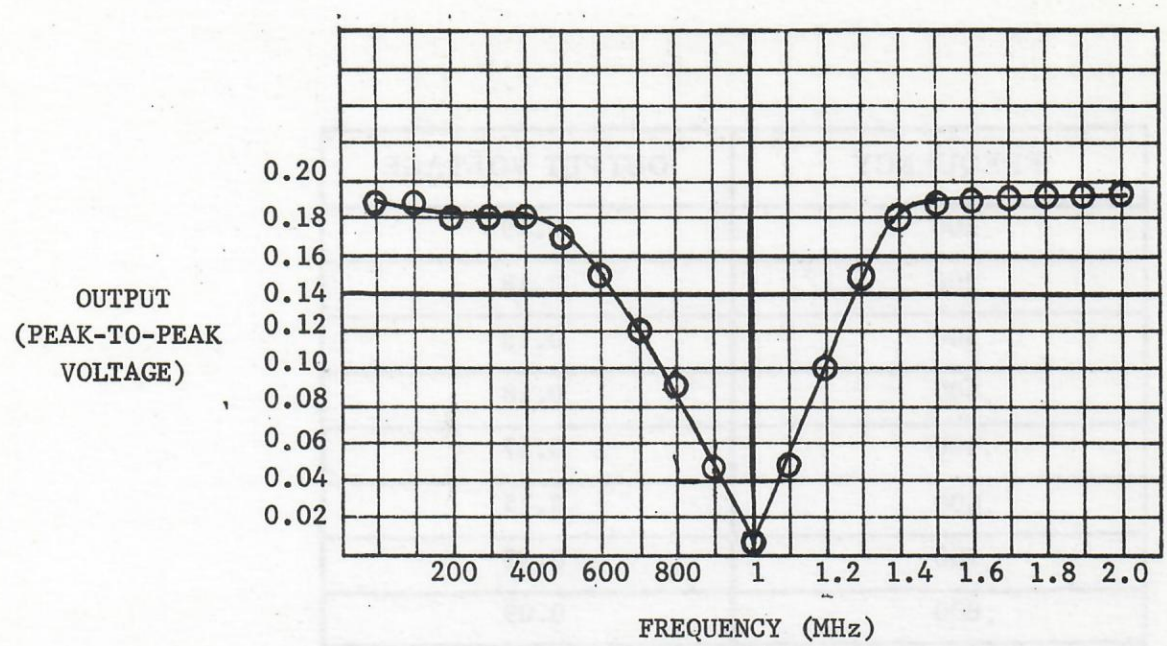
FREQUENCY TRAP FILTERS

8.

FREQUENCY	OUTPUT VOLTAGE
.100	0.19
.200	0.18
.300	0.18
.400	0.18
.500	0.17
.600	0.15
.700	0.12
.800	0.09
.900	0.05
1.0 M	0.01
1.1 M	0.05
1.2 M	0.10
1.3 M	0.15
1.4 M	0.18
1.5 M	0.19
1.6 M	0.19
1.7 M	0.19
1.8 M	0.20
1.9 M	0.20
2.0 M	0.20

FREQUENCY TRAP FILTERS

9. Graph of Results



10.

$$\text{REJECTION} = \frac{\text{MINIMUM VOLTAGE}}{\text{NOMINAL VOLTAGE}} = \frac{0.01}{0.18} = 0.05$$

REJECTION VOLTAGE RATIO = 0.05

REJECTION = 20 log 0.05 = 20(-1.3) = -26 DECIBELS

FREQUENCY TRAP FILTERS

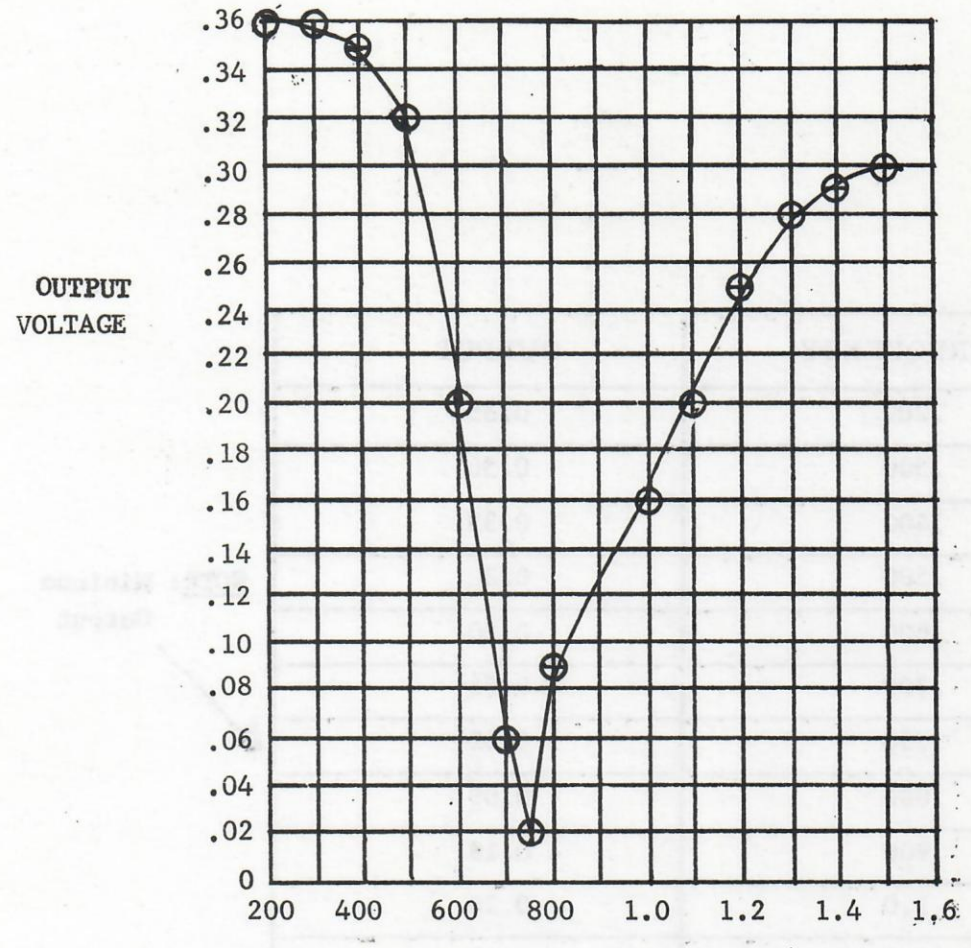
12. Data for Circuit 26-2.

FREQUENCY	OUTPUT
.200	0.36
.300	0.36
.400	0.35
.500	0.32
.600	0.20
.700	0.06
.750	0.02
.800	0.09
.900	0.16
1.0	0.20
1.1	0.23
1.2	0.25
1.3	0.28
1.4	0.29
1.5	0.30

NOTE: Minimum Output

FREQUENCY TRAP FILTERS

Graph of Results for Circuit 26-2.



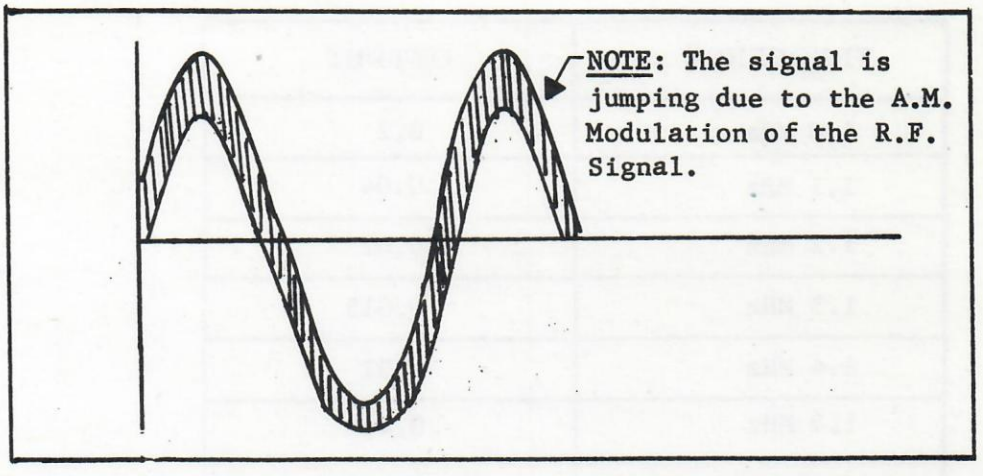
13. Filter Rejection

$$\text{REJECTION} = \frac{\text{MINIMUM OUTPUT}}{\text{NOMINAL OUTPUT}} = \frac{0.01}{0.24} = 0.04$$

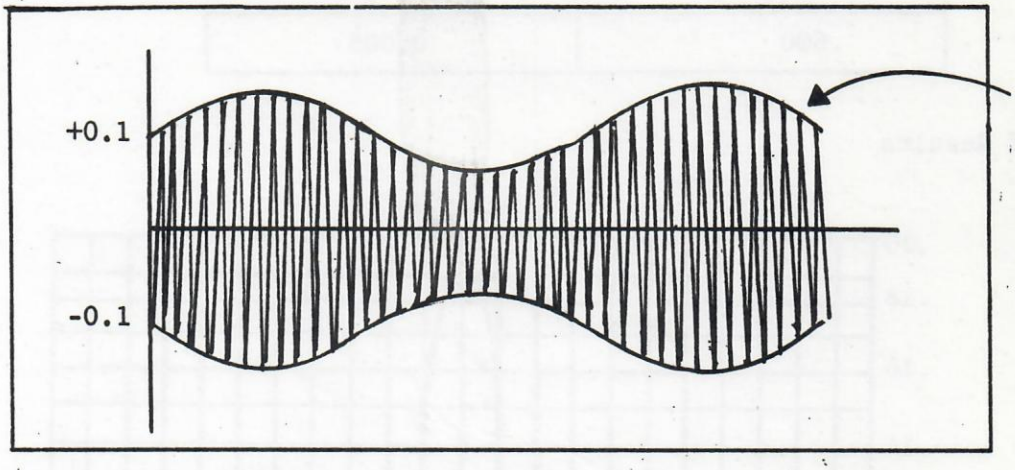
REJECTION (db) = 20 log (0.04) = -28 db

FREQUENCY TRAP FILTERS

14. INPUT SIGNAL (at the Junction of the 1K and 56K resistors)



OUTPUT SIGNAL

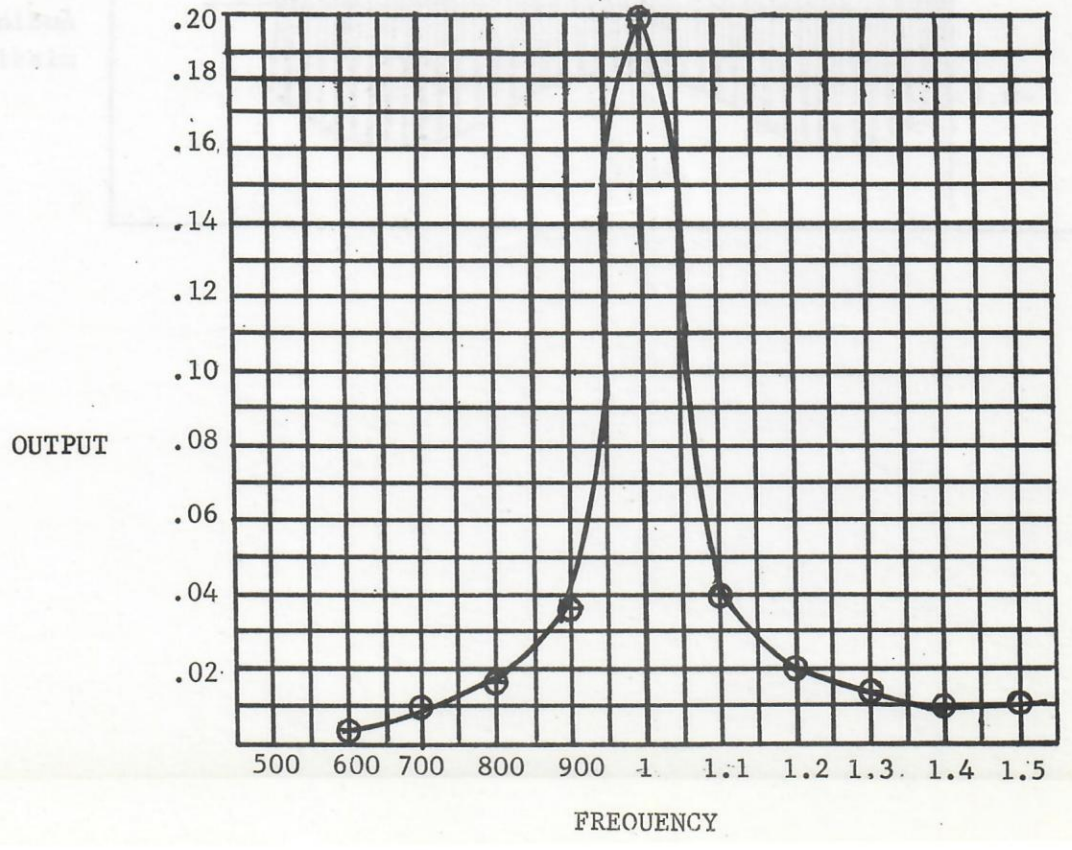


FREQUENCY TRAP FILTERS

15.

FREQUENCY	OUTPUT
1.0 MHz	0.2
1.1 MHz	0.04
1.2 MHz	0.02
1.3 MHz	0.015
1.4 MHz	0.01
1.5 MHz	0.01
.900	0.04
.800	0.018
.700	0.01
.600	0.005

Graph of Results



FREQUENCY TRAP FILTERS

16. Filter Attenuation

$$\text{FILTER ATTENUATION} = 20 \log \frac{\text{MINIMUM OUTPUT}}{\text{MAXIMUM OUTPUT}}$$

$$\text{FILTER ATTENUATION} = 20 \log \frac{0.01}{0.2} = 20 \text{ lob } 0.05 = -26 \text{ db}$$

FILTER ATTENUATION = -26 db

IMAGE FREQUENCIES

This experiment is aimed at explaining the purpose of the input tuned circuit in a superhetrodyne receiver. If the superhetrodyne principle is clear in the students mind then he will realize that the tuning of the local oscillator and the narrow bandwidth of the I.F. Amplifier are sufficient to allow the receiver to select one stations signals and reject all others. The tuned circuits in the I.F. strip will reject other nearby stations. Remind the student that the mixer will not only convert and amplify the received signal 455 KHz below the local oscillator, it will also convert the signal 455 KHz ABOVE the local oscillator frequency. The purpose of the input resonant circuit is to prevent this higher Radio signal, 910 KHz higher than the desired radio signal, from entering the mixer stage. The higher frequency which could be converted to the I.F. frequency by a particular local oscillator frequency is called the IMAGE FREQUENCY. The theory is explained in the experiment.

5. FIRST IMAGE FREQUENCY = 1.9 MHz

6. This is accurate to within the accuracy available on the R.F. Generator scale.

R.F. AMPLIFIER

The Common Base R.F. Amplifier circuit is tested. Note that this circuit has a tuned tank output. The maximum amplification will occur at the frequency to which the tank circuit is tuned.

4. Output Signal + Noise and Noise Voltage Measurement

OUTPUT

(Signal + Noise)	= 0.3	volts	← peak-to-peak
(Noise)	= 0.002	volts	← peak-to-peak

5. Calculation of Signal to Noise Ratio

$$\text{OUTPUT } \frac{(S+N)}{N} = \frac{0.3}{0.002} = 150$$

6.

INPUT Signal (S+N) = 0.003 volts p-p

7. R.F. Amplifier Gain

$$G = \frac{\text{OUTPUT } (S+N)}{\text{INPUT } (S+N)} = \frac{0.3}{0.003} = 100$$

$$G = 100$$

Care must be taken when performing this experiment to be sure that the Signals measured are the input and amplified output signals, and not a signal generated internally in the amplifier by undesired oscillation. If a students responses to the sections of this experiment differ widely from those given in this answer book, the students R.F. Amplifier may have been oscillating.

CRYSTAL AND FILTER CIRCUIT

The Crystal is tested for resonance and for "overtones" or harmonics.

The crystal is a very high Q tuned circuit. When it is placed in a series circuit the impedance of the crystal will be very high for all non-resonant frequencies. At the resonant frequency and the resonant frequency harmonics the crystal impedance will be low, resulting in a high output signal voltage.

2. The resonant peak is very sharp, so the R.F. Signal Generator must be tuned slowly near the resonant frequencies to find the peak. Note that 9 MHz is a good starting frequency.

   Is the Resonant Output Curve Sharp?

   Yes. The curve is so sharp that it is difficult to adjust the R.F. Signal Generator frequency to the peak output point.

CRYSTAL RESONANT FREQUENCY = 9.0 MHz

3. The second and third harmonics are difficult to measure if the instruments used are not intended for use above 15 MHz. We were able to measure the Second harmonic at a dial reading of 20 MHz. The third harmonic was not measurable. This experiment was performed with a 15 MHz oscilloscope and a simple R.F. Signal Generator. In general, students will have difficulty measuring these second and third harmonics if the classroom instrumentation is not rated for operation at these frequencies. Another factor effecting this measurement is the banana plug wires used to build the circuit.

   Recommendation is made for the instructor to personally attempt to make these measurements in class using his typical test equipment in order to determine the level of performance to be expected of his students.

CRYSTAL OSCILLATOR

The crystal is used in a Pierce Oscillator circuit. The output waveform is monitored and the frequency of oscillation is measured.

4. T = Period of oscillation $\approx 0.11\,\mu$ sec

$$f_{osc} = \frac{1}{T} = 9.09 \text{ MHz}$$

5. Note that the resonant frequency measured in experiment No. 29 and the frequency of oscillation are the same, 9 MHz. The frequency of this oscillator is determined by the resonant frequency of the crystal used.

FREQUENCY MULTIPLICATION

A transistor amplifier drives a tuned amplifier. The resonant circuit of the tuned amplifier is adjusted to 1 MHz. The input frequency is varied and is noted that, when 1 MHz is an even multiple of the input frequency, a 1 MHz output peak is obtained.

2. RESONANT FREQUENCY = 0.1 MHz

PEAK FREQUENCY	MULTIPLICATION
1 MHz	x1
500 KHz	x2
330 KHz	x3
250 KHz	x4
200 KHz	x5

C.B. RADIO

The student will build and test a C.B. Radio transmitter. The crystal on the F.M. Card is suitable for use in this circuit. Note that the Audio Transformer Card is used to Collector Modulate the Crystal Oscillator.

3. With the Signal Generator providing an Audio Modulating signal, the 10K POT must be adjusted to avoid overmodulating the output signal. The A.M. Modulated R.F. signal should be seen on the oscilloscope.

   When the microphone is used to modulate the transmitter, the 10K POT must be set at Full to achieve acceptable modulation levels.

4. Our transmitter output was received on channel 2 of a C.B. Receiver. The Antenna wire of our transmitter was placed in close proximity to the CB receiver antenna. The received signal was clear and the communication link provided an acceptable voice channel.

F.M. TRANSFORMER

The F.M. transformer is tested. Note that the transformer is tuned to 455 KHz.

4.

PIN (3) | Transformer Input = 5.6 volts PEAK to PEAK

5.

PIN (7) | Transformer Output = 3.2 volts PEAK to PEAK

6. Since the output Voltage is smaller than the Input Voltage the transformer is a Step Down.

7.

FREQUENCY	TRANSFORMER OUTPUT
400 KHZ	0.16 volts p-p
420 KHZ	0.3 volts p-p
440 KHZ	0.7 volts p-p
445 KHZ	3.2 volts p-p
460 KHZ	2.0 volts p-p
480 KHZ	0.58 volts p-p
500 KHZ	0.3 volts p-p

F.M. DEMODULATORS & SLOPE DETECTOR

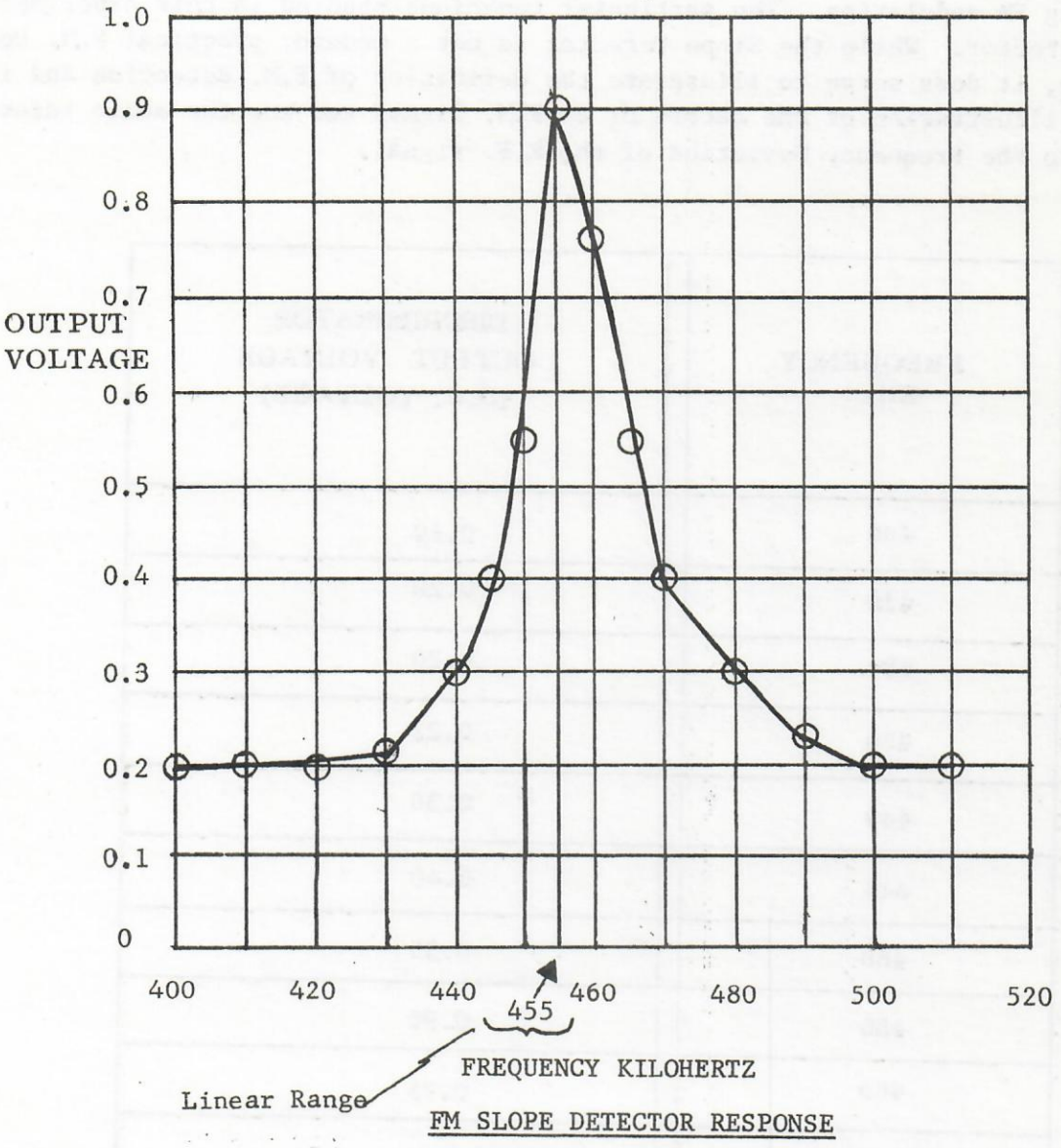
The Description section of the experiment explains the various techniques available for detecting FM modulation. The particular technique studied in this experiment is the slope detector. While the Slope Detector is not a modern, practical F.M. Dector in use today, it does serve to illustrate the definition of F.M. detection and it is a very good illustration of the nature of an F.M. Signal and how the audio information is coded into the Frequency Deviation of the R.F. signal.

3.

FREQUENCY KHz	DISCRIMINATOR OUTPUT VOLTAGE (D.C. VOLTAGE)
400	0.20
410	0.20
420	0.20
430	0.22
440	0.30
445	0.40
450	0.55
455	0.90
460	0.75
465	0.55
470	0.40
480	0.30
490	0.25
500	0.20
510	0.20

F.M. DEMODULATORS & SLOPE DETECTOR

4.



FM SLOPE DETECTOR RESPONSE

5.

FREQUENCY RANGE = 443 KHz to 455 KHz.

Note that the reported linear frequency range is below the resonant frequency of the transformer. There is also a usable linear frequency range above the transformer resonant frequency. When using a slope detector to detect F.M. signals the transformer resonant frequency must be tuned to half the linear frequency range above or below the center frequency of the incoming signal.

F.M. DISCRIMINATOR

The Foster-Seeley F.M. Discriminator circuit is built and tested. Note that in this test the Limiter circuit is not used. This makes the experiment easier to connect and test. Without a limiter on the input to eliminate amplitude variations at the input to the discriminator, the output voltage will be effected by amplitude variations of the R.F. Signal Generator. This may cause a slight assymetry in the output curve.

3. Output Data

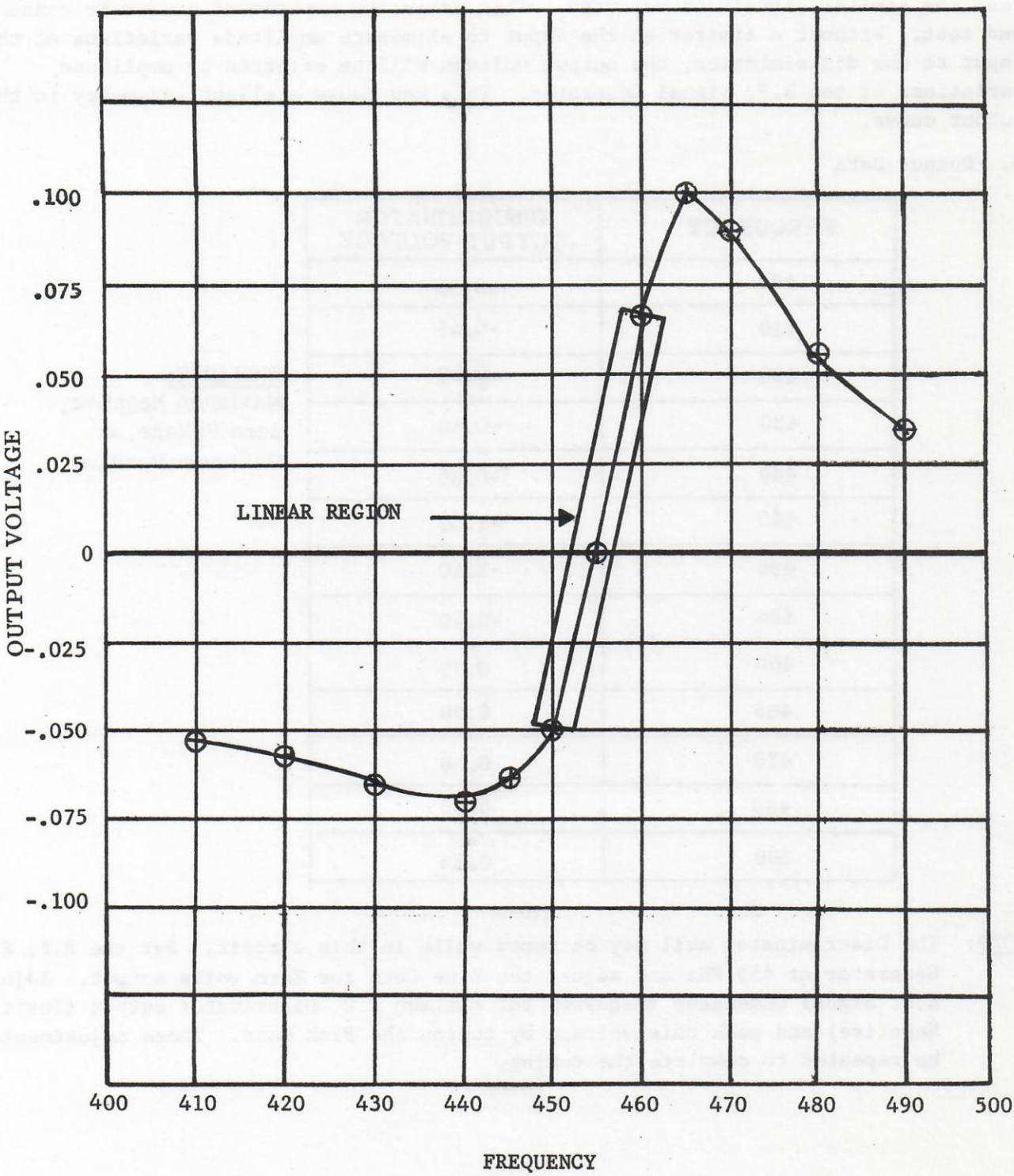
FREQUENCY	DISCRIMINATOR OUTPUT VOLTAGE
400	-0.35
410	-0.45
420	-0.50
430	-0.60
440	-0.80
445	-1.00
450	-1.10
455	-0.40
460	0.75
465	0.90
470	0.80
480	0.60
500	0.30

INCLUDE:
Maximum Negative,
Zero Voltage, &
Maximum Positive

NOTE: The Discriminator coil may be tuned while in this circuit. Set the R.F. Signal Generator at 455 KHz and adjust the Blue Core for Zero volts output. Adjust the R.F. Signal Generator frequency for maximum D.C. Discrimator output (Positive or Negative) and peak this voltage by tuning the Pink Core. These adjustments may be repeated to complete the tuning.

F.M. DISCRIMINATOR

4. OUTPUT CURVE



Note that from 450 KHz to 460 KHz the circuit D.C. output varies proportional to the input frequency.

F.M. DISCRIMINATOR

5.

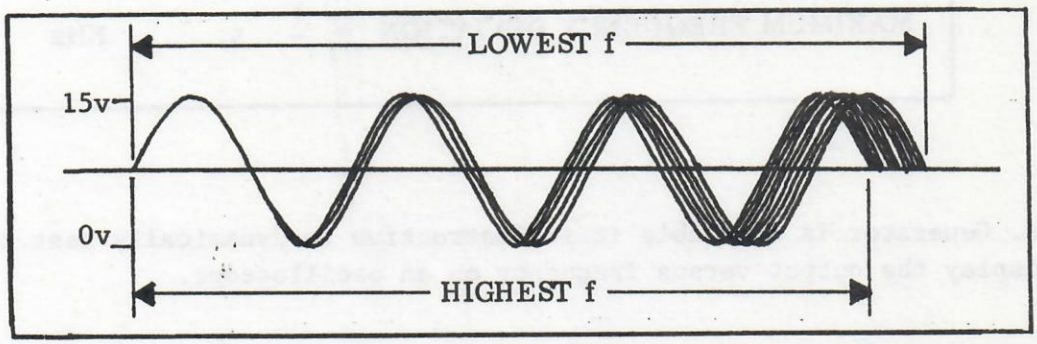
CENTER FREQUENCY	=	455	KHz
MAXIMUM FREQUENCY DEVIATION	= $\pm$	5	KHz

If an F.M. Generator is available it is instructive to dynamically test the Discriminator and to display the output versus frequency on an oscilloscope.

F.M. TEST GENERATOR

This experiment demonstrates the use of a Varactor Diode to generate an F.M. signal and it familiarizes the student with the typical practical waveforms associated with F.M. Signals. A method for determining the frequency deviation of the F.M. signal directly will be used.

4. Observed Waveform



5.

MEASUREMENT	LOWEST f	HIGHEST f
NUMBER OF CYCLES:	5	5
TIME:	9.7μ sec	9.0μ sec

CALCULATION	LOWEST f	HIGHEST f
FREQUENCY:	515.5 KHz	555.5 KHz

6. This frequency can be varied by rotating the Tuning Slug on the R.F. Coil. Rotate the knob by a small amount.

   Does the frequency change? YES

   This frequency change occurs due to the change in the value of the inductance of T2 in the collector resonant circuit.

F.M. TEST GENERATOR

7. The frequency can also be varied by slightly adjusting the D.C. Bias on the Varactor. Adjust the Bias 10K POT by a small amount.

   Does the frequency change? YES

   This frequency change is caused by the variation in D.C. bias on the Varactor Diode. By changing the reverse bias, the capacitance of the varactor diode is changed. This capacitance is part of the collector resonant circuit and causes the oscillator frequency to change.

8.

CAPACITANCE	FREQUENCY
No extra capacitor (SET AUDIO GENERATOR AMPLITUDE TO ZERO) i.e. NO F.M.	588.2 KHz
150 pfd Capacitor in parallel with Varactor	555 KHz
220 pfd Capacitor in parallel with Varactor	526 KHz
Series 150 pfd Cap. (Substitute 150 pfd for 0.25 mfd Cap.)	909 KHz
Series 220 pfd Cap. (Substitute 220 pfd for 0.25 mfd Cap.)	833 KHz

F.M. TEST GENERATOR

10. Are you able to receive a Tone? YES

    Do you observe a Null? YES

NOTE: When performing this portion of the experiment the oscillator must be tuned to a region of the A.M. band where there is no radio station so that the tone may be monitored without interference from another signal. Also the modulation level must be very low. If this is done the Null will be very noticable. The null may also be observed by tuning the radio to receive the tone and then varying the oscillator frequency using the adjustment on T2.

TRANSMISSION FREQUENCY = 900 KHz

11. Are you able to receive the voice transmission? YES

    The voice can be heard quite clearly using a small portable transistor radio. The modulation level (frequency deviation) is small when using the microphone so the deviation will be observed on the oscilloscope only if many cycles of the output are displayed by setting the oscilloscope sweep rate at a slower setting (5μsec/cm uas used in preparation of the answer manual.)

    If you hum loudly into the microphone and tune the receiver, the null and the two audible frequency settings will be quite evident.

12. Was a series capacitor necessary? NO

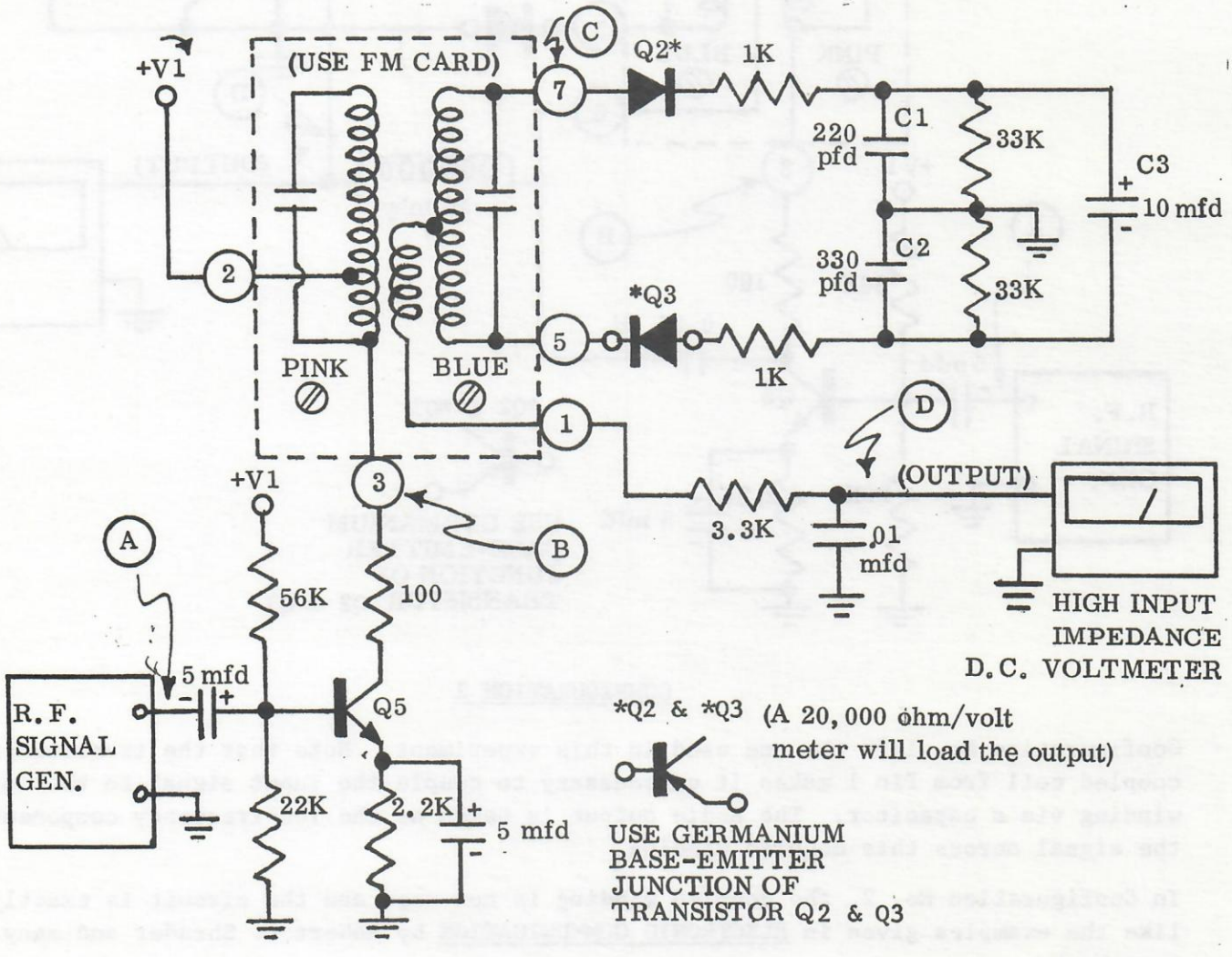
    What size was used? NONE

13. 455 KHz is obtainable, a 220 pfd capacitor was used in parallel with the varactor diode to set this frequency. The two tuning points are heard very clearly, remember, keep the amplitude of the Audio modulating signal very small.

F.M. RATIO DETECTOR

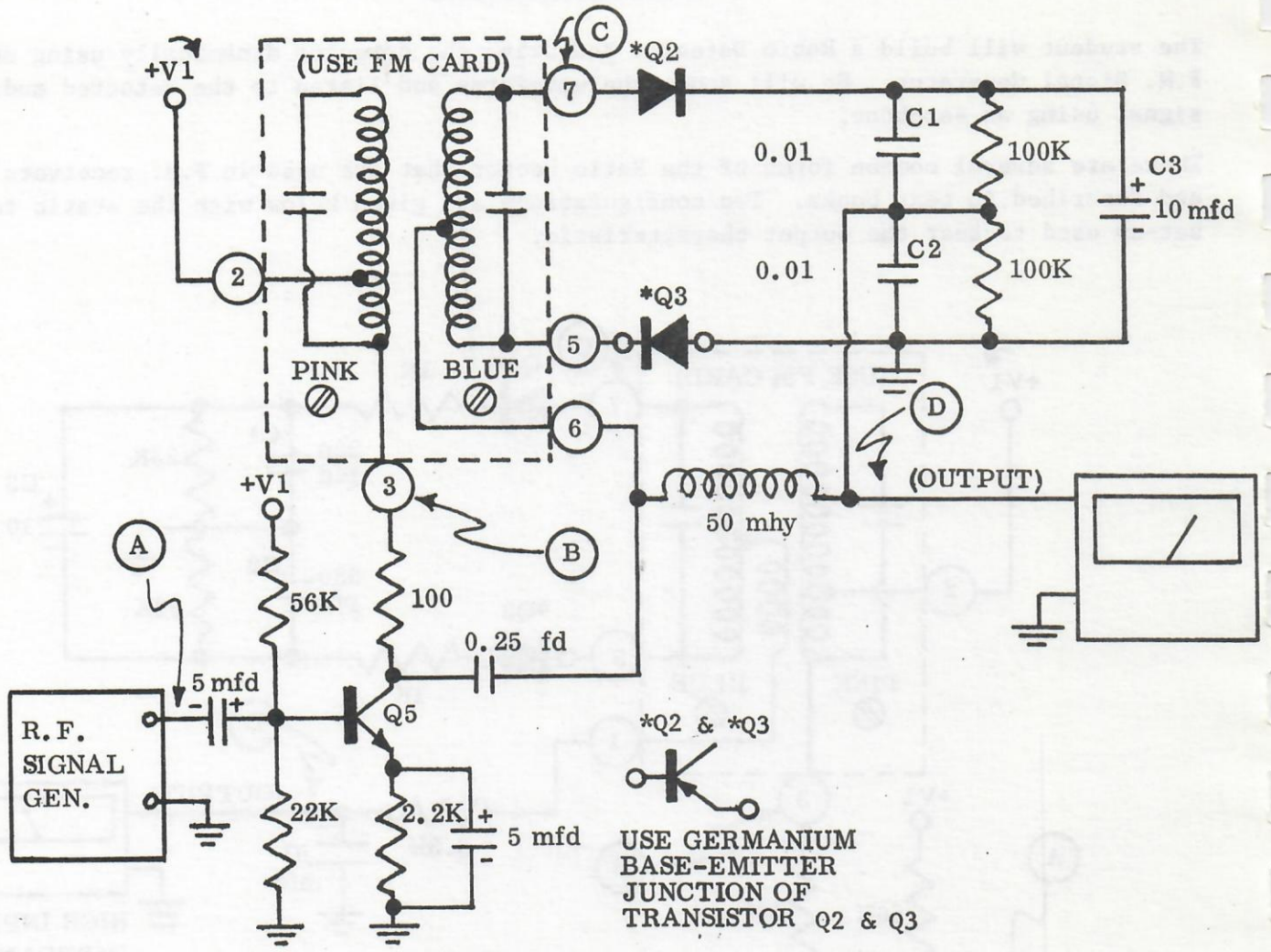
The student will build a Ratio Detector and drive the detector dynamically using an F.M. Signal Generator. He will study the waveforms and listen to the detected audio signal using an earphone.

There are several common forms of the Ratio Dector that are used in F.M. receivers and described in text books. Two configurations are given below with the static test set-up used to test the output characteristic.



CONFIGURATION 1

F.M. RATIO DETECTOR



CONFIGURATION 2

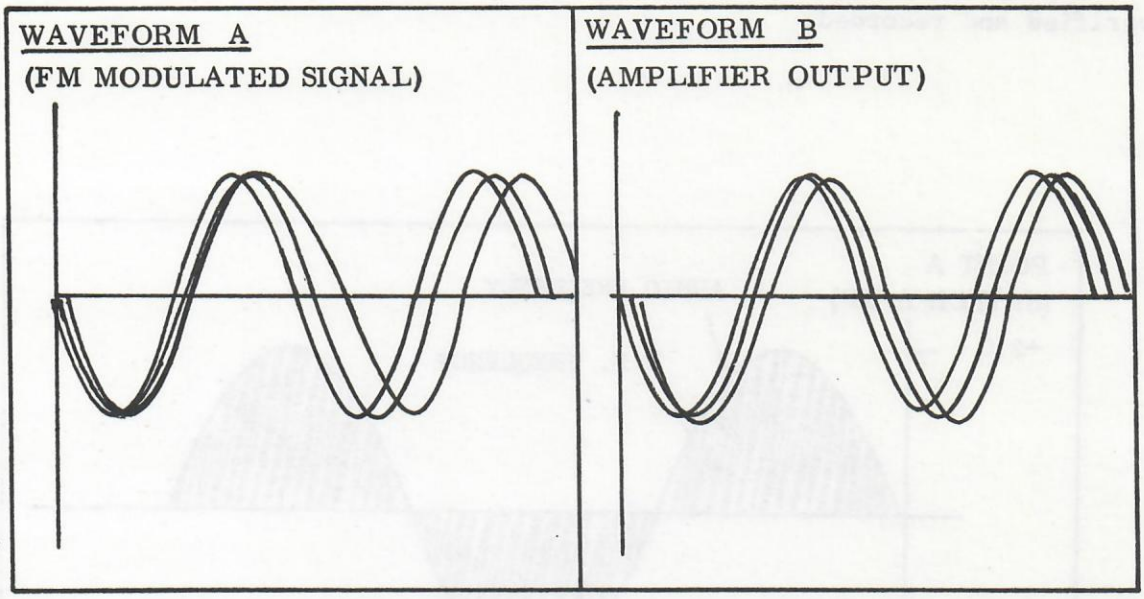
Configuration No. 1 is the one used in this experiment. Note that the transformer coupled coil from Pin 1 makes it unnecessary to couple the input signal to the output winding via a capacitor. The Audio output is taken as the low frequency component of the signal across this coupled winding.

In Configuration No. 2, the coupled winding is not used and the circuit is exactly like the examples given in ELECTRONIC COMMUNICATION by Robert L. Shrader and many other text books.

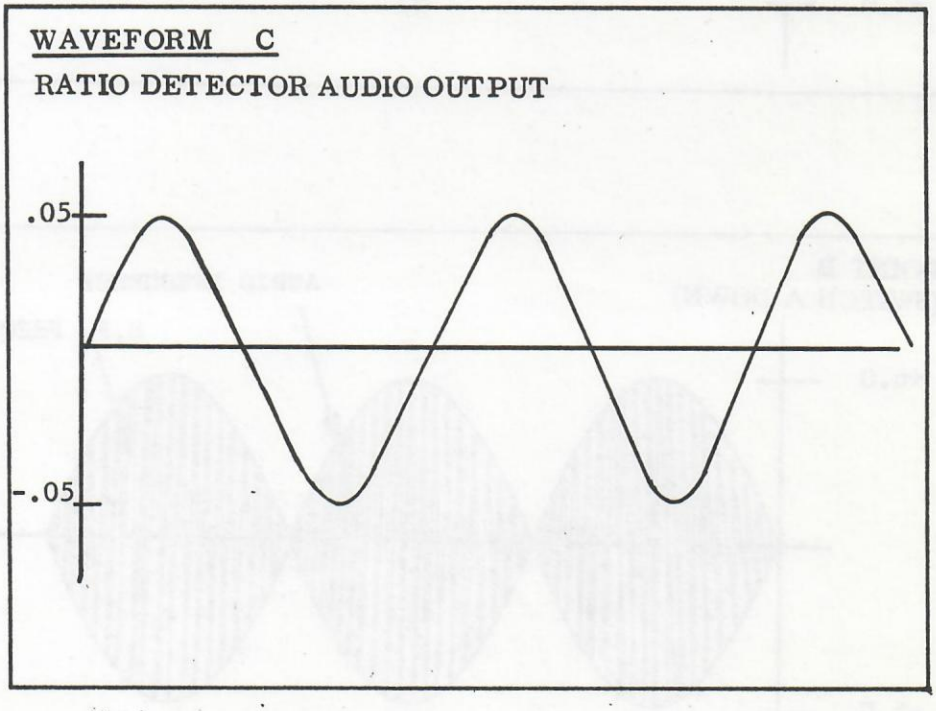
Either one of these circuits may be built and tested by the student, using the same techniques as given in the F.M. DISCRIMINATOR Experiment No. 35.

F.M. RATIO DETECTOR

3.



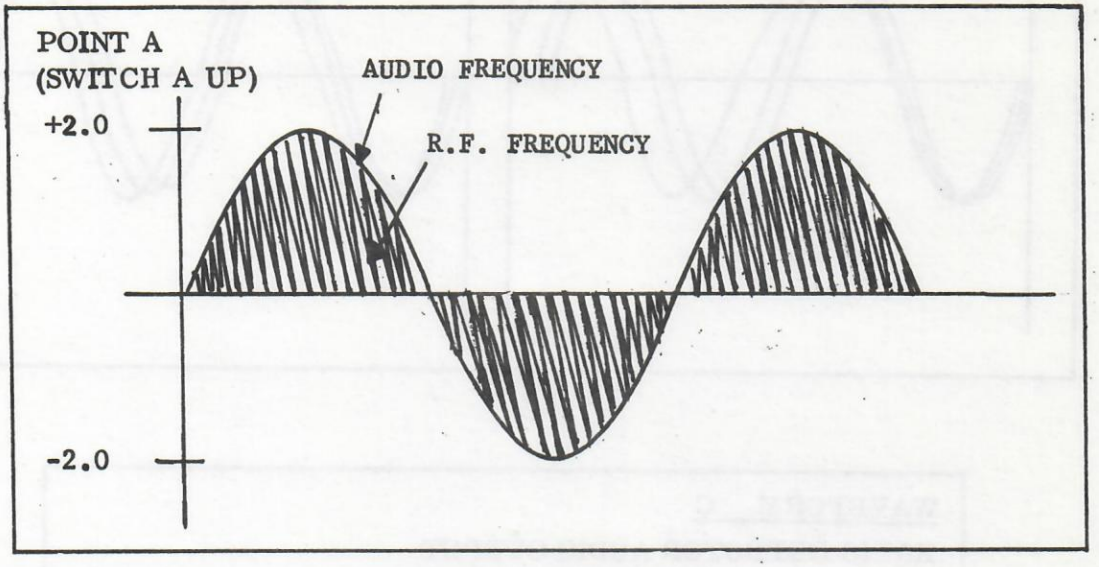
5.

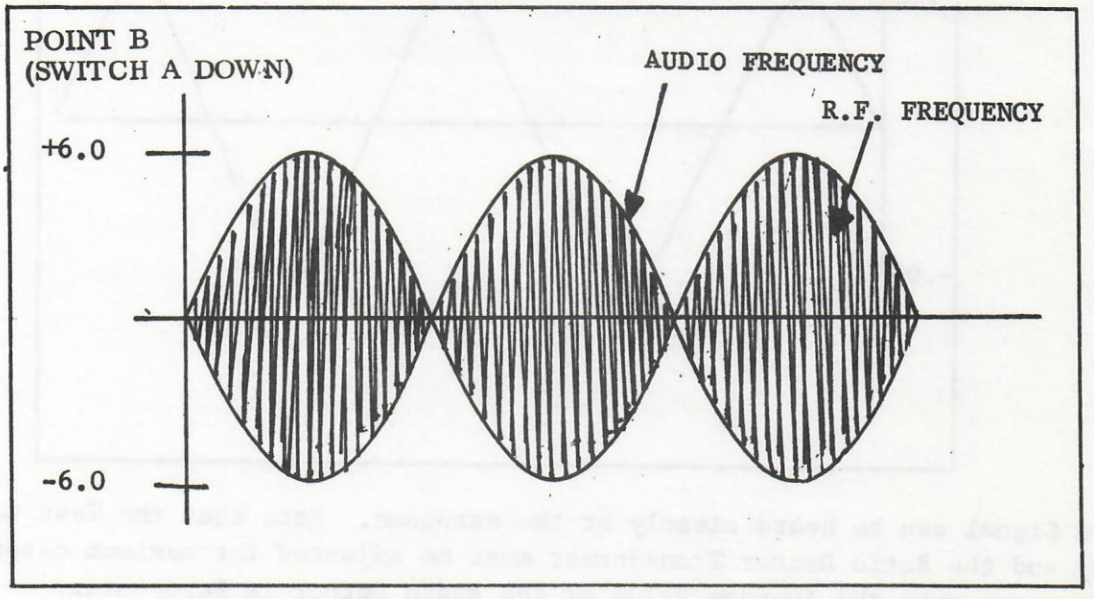


The Audio Signal can be heard clearly at the earphone. Note that the Test Generator frequency and the Ratio Dector Transformer must be adjusted for maximum output amplitude. This will occur when the Average Value of the Audio Output is Zero volts.

SINGLE SIDEBAND and BALANCED MODULATOR

A Balanced Modulator is tested and the generation of the Suppressed Carrier AM Output is verified and recorded.





SINGLE SIDEBAND and BALANCED MODULATOR

4. The outputs measured in these tests correspond exactly to the expected output signals.

5. When the 10K POT is set at zero (no Audio Signal) the R.F. Carrier output voltage is small, 0.02 volts peak to peak.

CARRIER OUTPUT - NO AUDIO = 0.02 volts peak to peak

MAXIMUM R.F. CARRIER AMPLITUDE - MAXIMUM AUDIO = 4 volts peak to peak

$$\text{CARRIER SUPPRESSION} = \frac{\text{R.F.(No Audio)}}{\text{Max R.F. Carrier}} = \frac{0.02}{4} = 0.005$$

expressed in dB the Carrier Suppression is:

$$\text{CARRIER SUPPRESSION (db)} = 20 \log \frac{\text{R.F. No Audio}}{\text{Max R.F. Carrier}}$$

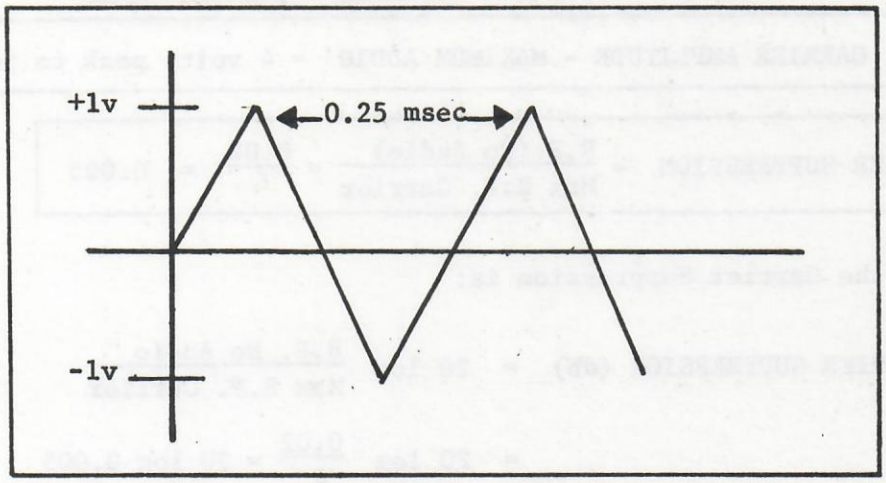
$$= 20 \log \frac{0.02}{4} = 20 \log 0.005$$

CARRIER SUPPRESSION (dB) = 20(0.69 - 3) = 20(-2.31) = -46.2 dB

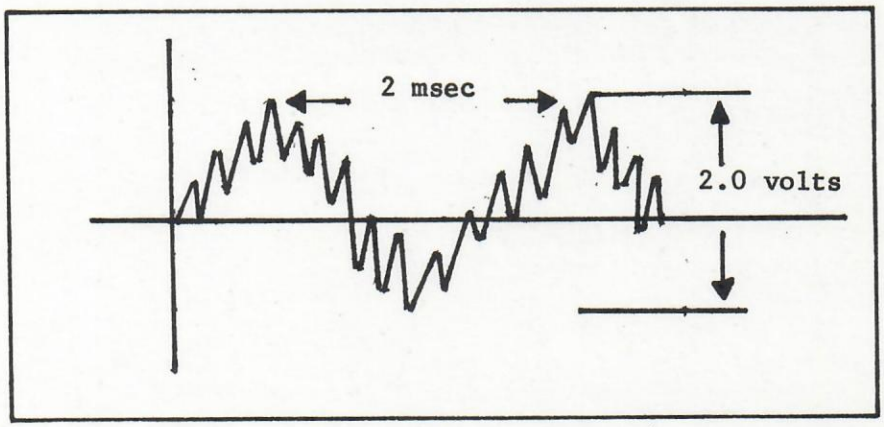
STEREO MULTIPLEXING

Two separate Audio Signals at different frequencies are used as the left and right channel signals of a Stereo signal. A Phase Splitter and two Adder circuits are used to generate the L + R and L - R mixed signals. These signals are then decoded in an output balancing network.

3. SKETCH RIGHT Channel

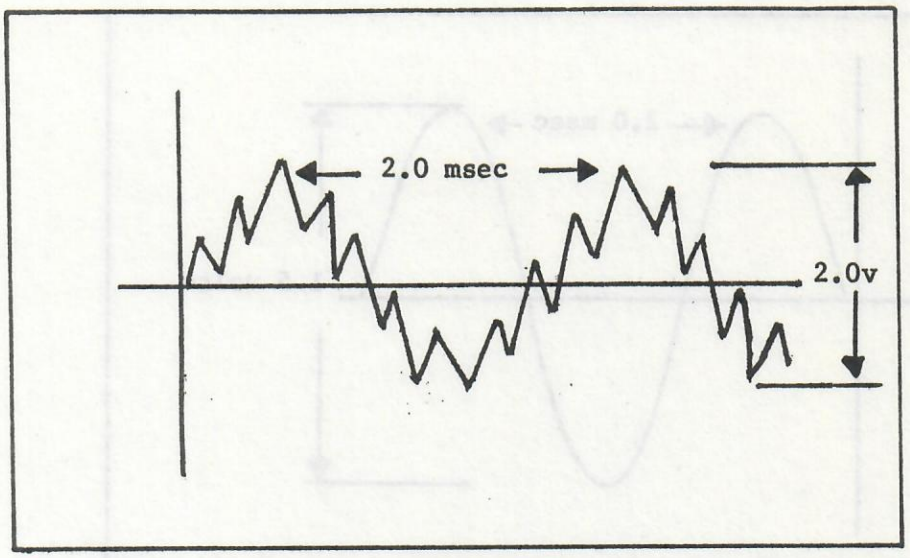


4. SKETCH RIGHT + LEFT Channel (Test Point #1)

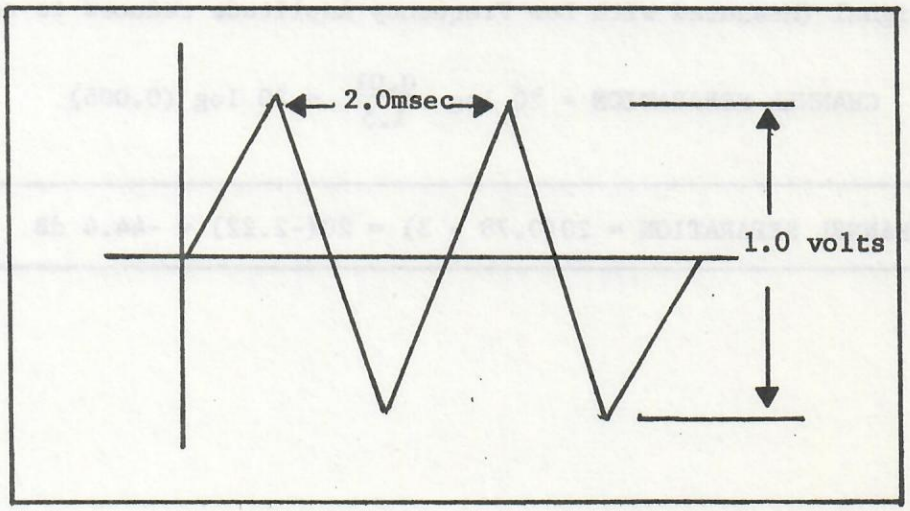


STEREO MULTIPLEXING

5. SKETCH LEFT - RIGHT (Test Point #2)

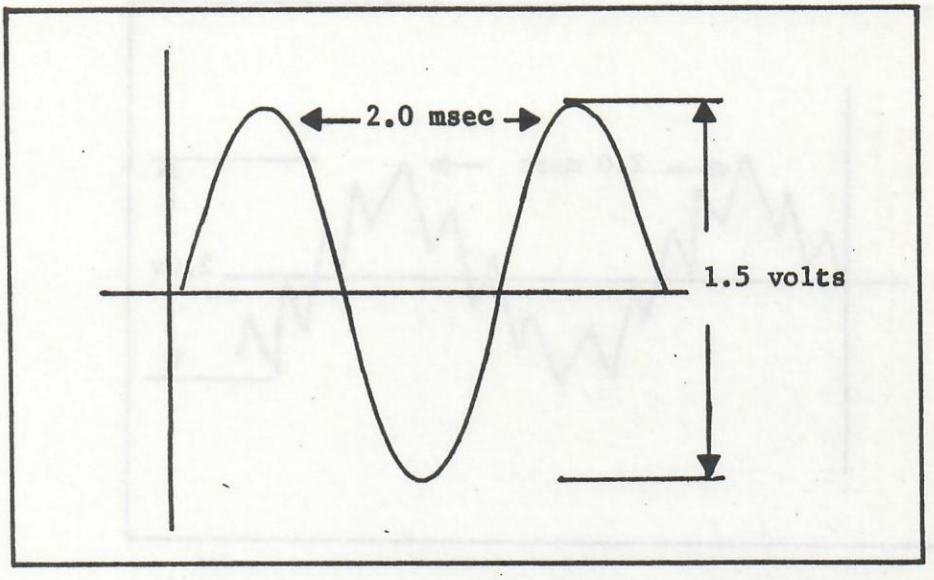


6. DECODED RIGHT Stereo Channel (Switch A UP)



STEREO MULTIPLEXING

7. DECODED LEFT Stereo Channel (Switch A DOWN)



The channel separation at the output is excellent. When viewing the low frequency output there is no indication observable of multiplexing after the 1 Meg balance.

A calculation may be made of the channel separation.

LOW FREQUENCY OUTPUT = 1.5 volts p-p

High Frequency Signal (Measured with Low Frequency Amplitude reduced to zero) = 0.01v p-p

$$\text{CHANNEL SEPARATION} = 20 \log \frac{0.01}{1.5} = 20 \log (0.006)$$

$$\boxed{\text{CHANNEL SEPARATION} = 20(0.78 - 3) = 20(-2.22) = -44.4 \text{ dB}}$$

LINEAR INTEGRATED CIRCUITS

This experiment uses the Operational Amplifier as an Inverting Amplifier. The gain for this configuration is measured and calculated. The theory of operation and the formula for gain are in the experiment. Note that this is an application of an Integrated Circuit which contains many transistors, resistors and diodes in a single package. The power and flexibility offered by such packaging has revolutionized the electronics industry and resulted in electronics devices being lower priced and smaller in size than ever believed possible.

3. Input/Output Data

SWITCH A UP	V_x = 5.2 v peak to peak
SWITCH A DOWN	V_{out} = 1.06 v peak to peak

4. Gain Calculation

$$G = \frac{100\ V_x}{V_{out}} = \frac{100 \times 1.06}{5.2} = 20.3$$

G = 20.3

5. The gain and the ratio differ by 10%. This is due to inaccuracies in the resistor values.

6.

		MEASURE		CALC. GAIN	CHECK
		Switch A UP	Switch A DOWN		
R_f	THEOR GAIN	V_x	V_{out}	$100\frac{V_{out}}{V_x}$	
22K	22	5.2	1.06	20.3	✓
1K	1	5.0	0.045	0.9	✓
100K	100	5.0	4.5	90	✓
15K	15	5.0	0.7	14	✓
* 1M	1000	5.0	Output Signal Distorted	No Valid Gain	✓
R_f = 3.3K R_{in}= 10K	0.33	5.0	0.016	0.32	✓
R_f = 1K R_{in}= 3.3K	0.3	5.0	0.015	0.30	✓

LINEAR INTEGRATED CIRCUITS

7. Actual I.C. Measurement

SWITCH A UP	$V_x = 5.0$
SWITCH A DOWN	$V_{out} = 1.0$

8. Gain Calculation

$$G = \frac{100\ V_{out}}{V_x} = \frac{100 \times 1}{5} = 20$$

G = 20

9. The 10% error is caused by the error in the resistor values.

BOOK IV TELECOMMUNICATIONS ERRATA & CLARIFICATION SHEET
(FOR EDITION DATED 1976, 1977)

UNIT 8

EXP. No. 1

page 1: Figure 1-1; Add 100 ohm resistor in series with the transistor emitter.

page 2: Step 3; change "R(emitter) = 0 OHMS" to "R(emitter) = 100 OHMS, 10K POT set to minimum."

EXP. No. 4

page 1: Figure 4-1 Schematic Diagram change "220 mfd to "220 pfd"

EXP. No. 5

page 2: Line 6, change "You will now adjust the oscillator frequency to be exactly 300 Hertz using a 60 Hertz reference and a Lissajous pattern on the oscilloscope." to "You will now adjust the oscillator frequency."

Delete Paragraph 6.

EXP. No. 7

page 1: Figure 7-1: Add D.C. Meter with +0.5 volt input connected to cathode of D5 and the (-) input connected to Ground.

EXP. No. 9

page 1: Schematic Diagram Figure 9-1, Add + symbol to 100 mfd capacitor at the end connected to the base of Q5. Add - to other side of capacitor.

EXP. No. 11

page 1: Figure 11-1; Change Q5 in OUTPUT POWER AMPLIFIER TO Q3.

EXP. No. 13

page 4: Line 1; Change "... carrier frequency. The 10K POT..." to "...carrier frequency. Set the 1M POT Bias at the Lowest Voltage Level for oscillation. The 10K POT..."

EXP. No. 14

page 2:

TABLE 3rd Row reads 500 OHMS $\frac{3000}{500}$ = 6 2.45

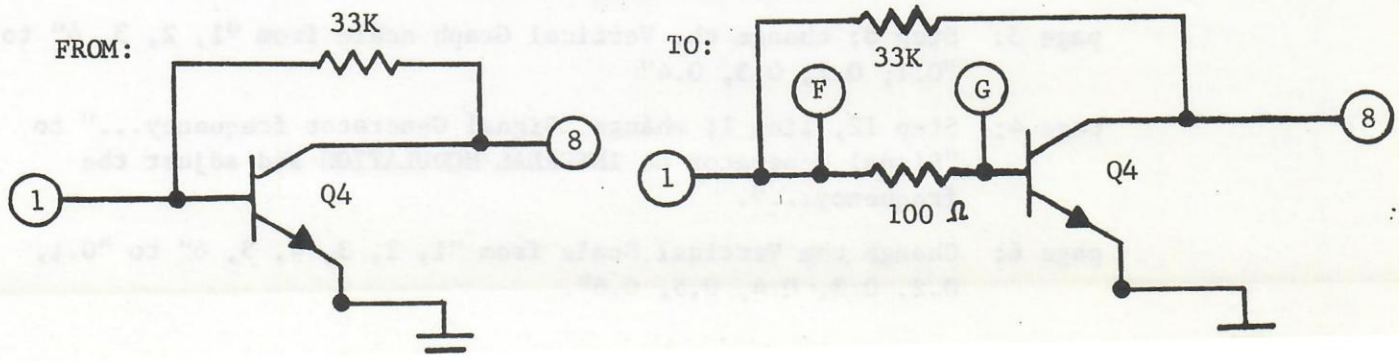
TABLE 4th Row reads 125 OHMS $\frac{3000}{125}$ = 24 4.89

TABLE 5th Row reads PIN 8 6 7

Add Note below Table: Because the Transformer Impedance Ratios are related by N^2 (the turns ratio squared) the Center Tapped Impedance is ¼ the full winding impedance.

EXP. No. 16

page 1: Figure 16-1; Change 100 ohm resistors connected from Transformer pin 2 to ground to 1K ohm. Change the base circuit of Q4;



UNIT 8

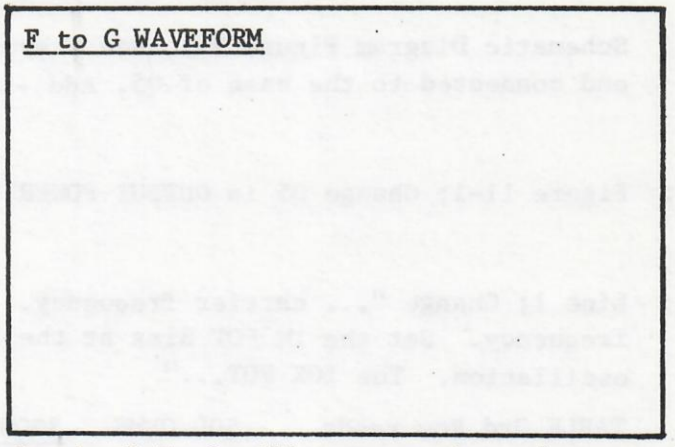
EXP. No. 16 (continued)

page 2: Procedure step 2 Change "Monitor the driver output signal at point B." to "Monitor the speaker output signal at point E."

Procedure step 3 Change "Adjust the collector bias feedback 100K POT for a maximum, undistrted CLASS A signal at point B." to "Adjust the collector bias feedback 100K POT and the 10K volume POT for a maximum undistorted signal at point E.

page 3: Below Box for E OUTPUT WAVEFORM:
Add "5. Connect the Oscilloscope Common to Point G and the VERTICAL INPUT to point F. Record the waveform of the voltage measured across F,G. This waveform is proportional to the base current into Q4. Note that base current and therefore collector current flows only for ½ of the signal cycle indicating class C operation of the transistor."

page 3: Add Box for F to G WAVEFORM



EXP. No. 17 Figure 17-1; In the R.F. Oscillator section, the capacitor connected across the inductor in the base circuit Change "mhy" to "pfd".

In the connection from the base of Q4 to the positive of the 5mfd capacitor, insert 15K resistor.

Change 5mfd capacitor from the base of Q4 to the base of Q5 to 0.001mfd

EXP. No. 21

page 2: Procedure step 6, line 3; change "3 volts peak to peak" to "0.3 volts peak to peak".

page 3: Step 8; change the Vertical Graph scale from "1, 2, 3, 4" to "0.1, 0.2, 0.3, 0.4"

page 4: Step 12, line 1; change "Signal Generator frequency..." to "Signal Generator on INTERNAL MODULATION and adjust the frequency...".

page 6: Change the Vertical Scale from "1, 2, 3, 4, 5, 6" to "0.1, 0.2, 0.3, 0.4, 0.5, 0.6".

UNIT 8

EXP. No. 22

page 3: Step 4, insert the following sentence between the 1st and 2nd sentences.
"The input signal amplitude from the signal generator must be reduced to result in an undistorted output waveform."

EXP. No. 24

page 1: Schematic Diagram Figure 24-1 Change "-V*" to "-V" (5 places)
On diode connected to the collector of Q5 change: "D1" to "D3"

EXP. No. 26

page 1: Figure 26-2 Shunt Trap, change 150 pfd capacitor to 0.001 mfd capacitor.

page 4: Step 8, Add "Check the input signal amplitude for each frequency tested and set the R.F. Generator amplitude for the same level for each frequency used. Take data from 100 KHz to 2.0 MHz in 100KHz increments.

page 6: Step 12, add; Use the same R.F. Generator input amplitude for each frequency tested. Make test from 200 KHz to 1.6 MHz in 100 KHz increments.

EXP. No. 28

page 4: Below Step 8, add:
"9. When measuring the input Signal + Noise the tuning capacitor on the Superhet Card may have to be adjusted for peak input voltage. Care must be taken that the signals measured are actually the signal generator output and not oscillation of the amplifier. This can be tested by changing the R.F. Generator amplitude and noting that the amplitude of the signal being measured varies correspondingly.

EXP. No. 31

page 2: Procedure, step 2, line 1; change "Vary the input R.F. frequency and observe the output..." to "Set the input R.F. frequency at 1 MHz and adjust the tuning knob for peak output...".

EXP. No. 32

page 5: Schematic Diagram Figure 32-3 add the following notation to the right of transformer connected to the collector of Q5:
"AUDIO TRANSFORMER CARD"
Remove 0.01 mfd capacitor connected from the base of Q7 to ground.

EXP. NO. 33

page 1: Schematic Diagram Figure 33-1; Remove the number 5 and the circle around it at the junction of C1 and the transformer primary.

UNIT 8

EXP. No. 35 (continued)

page 2: Line 7; change "Capacitor C4 is the detector filter capacitor" to "Capacitor C4 and C5 are the detector filter capacitors".

page 3: Procedure step 1, line 4; change "The bottom diode..." to The diodes..."
Line 5; change "transistor Q5..." to "transistors Q5 and Q6..."

EXP. No. 36

page 4: Step 8; Table column marked CAPACITANCE, top line, change "(SET 10K POT ZERO) i.e. No F.M." to "(SET AUDIO GENERATOR AMPLITUDE TO ZERO) i.e. No F.M."

EXP. NO. 37

page 1: Schematic Diagram Figure 37-1, change "D5" to "Q2*"
Change "(6)" to "(5)" on the transformer Secondary Connections.
Change "*Q3" to "*Q3 & *Q2"

page 2: Change "This circuit will not respond...must be used as shown in the diagram." to "This circuit will respond to a test where the R.F. signal frequency is varied from a signal generator. This test would be exactly the same as performed in the DISCRIMINATOR Experiment No. 35.
Procedure, step 1, line 2, change "DETECTOR CARD" to "CARD:.
Step 2, at end of step, add "Set the Audio Generator at 200 Hz.

EXP. No. 38

page 3: Line 24, change "RF L-C Filter" to RF R-C Filter"

EXP. No. 40

page 4: Step 4 change "$G = \frac{100V_x}{V_{out}}$" to "$G = \frac{100V_{out}}{V_x}$"

Step 6, below the table add:

*The Amplifier will saturate and clip the output signal giving a false result.

Step 6, Table, column marked THEOR GAIN Row 6, from top; change "3.3" to "0.33"

In bottom table, column 5, change "V_x" to "V_{out}" and "V_{out}" to "V_x"

page 5: Step 8, change "$G = \frac{100V_x}{V_{out}}$" to "$G = \frac{100V_{out}}{V_x}$"